AN APPLICATION OF GRAVITY MODEL THEORY USING A SMALL SAMPLE OF ORIGIN-DESTINATION DATA

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by

B.L.SMITH

Joint Highway Research Project

PURDUE UNIVERSITY
LAFAYETTE INDIANA

Informational Report

AN APPLICATION OF GRAVITY MODEL THEORY

USING A SMALL SAMPLE OF ORIGIN-DESINATION DATA

TO: K. B. Woods, Director
Joint Highway Research Project

October 31, 1963

FROM: H. L. Michael, Associate Director
Joint Highway Research Project

File: 3-2

A report entitled "An Application of Gravity Model Theory Using a Small Sample of Origin-Destination Data" by Bob L. Smith, Graduate Student at Purdue University is attached. The research reported by Mr. Smith was performed under the direction of Professor H. L. Michael and financed by the Kansas State Highway Commission and the Bureau of Public Roads. The research was conducted on a Kansas city and primarily conducted by Mr. Smith in absentia. Mr. Smith also used the report as his thesis requirement for the Ph.D. degree from Purdue University.

The report is not a result of Project research but as is our custom is presented to the Board as information on an area of interest and concern to the Board. A paper prepared from this report has been submitted to the Highway Research Board.

The report is presented as information.

Respectfully submitted,

Harold L. Michael

Harold L. Michael, Secretary

HLM:bc

Attachment

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by

Bob L. Smith

Graduate Student

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Prepared as Part of an Investigation

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Kansas State University

in cooperation with

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U. S. Department of Commerce

and

School of Civil Engineering
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Lafayette, Indiana

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ABSTRACT

Smith, Bob L., Ph. D., Purdue University, January 1964. An Application of Gravity Model Theory Using a Small Sample of Origin-destination Data. Major Professor: Harold L. Michael.

This thesis reports the results of a study concerned with an application of the gravity model in which the model parameters -- trip production, trip attraction and travel time factors -- were estimated using data obtained from a small sample of home interviews taken in a sample of origin-destination (O-D) survey zones.

A gravity model was calibrated using the estimations of trip productions and attractions obtained from the small sample of O-D interviews. An additional model was calibrated using the productions and attractions obtained from the comprehensive O-D survey. The resulting distributions were compared with the distributions obtained from the comprehensive survey.

In the sample study, the information obtained from interviews from 402 dwelling units in 14 selected zones in the survey area was utilized. The comprehensive O-D study consisted of 2,528 interviews obtained from a 20 per cent sample of dwelling units from all 83 zones in the survey area. The comprehensive survey was conducted in 1959 in Hutchinson, Kansas which had a population of approximately 38,000 persons. The study was limited to the consider-

ation of auto-driver trips in which each trip had both its origin and destination within the survey area.

The auto-driver trips were classified according to trip purpose and the three trip purposes of home-work, home-other, and non-home were studied in detail.

The study was concerned with "present day" traffic rather than with the estimation of future traffic; however the data used in the development of estimating equations for trip attractions and trip productions were those which one could expect to be obtained quickly and economically, and that one could expect to estimate reasonably well for the future.

Current zonal trip productions and attractions were adequately estimated from the mathematical models developed from the small sample of home interviews. Best estimates resulted for home-based trip productions, but estimates of non-home-based trip productions and all trip attractions appeared to be adequate for planning purposes.

Travel time factors for the distribution of trips were satisfactorily estimated by calibrating the gravity model with trip length frequency data developed from the small sample of home interviews.

The gravity model using trip productions and travel time factors developed from the small sample of home interviews distributed trips among all zones to give an adequate reproduction, for planning purposes, of the trip distribution obtained in the comprehensive O-D study.

INTRODUCTION

Since the end of World War II, the increase in size of urban areas and the increase in automobile ownership have created new and involved transportation problems. Organizations such as the Bureau of Public Roads, state highway departments and other federal, state and municipal agencies are vitally concerned with the making of decisions which relate to both when and where to construct new roads and streets or to improve existing ones.

In order to carry out the planning of solutions to a particular urban transportation problem, the agency or persons involved must have available factual data which describe the problem as it exists and from which estimates may be made of the problem as it may exist in the future. The gathering and the analysis of such data is called a transportation study. A large number of such studies have been made in the last ten years and concerted efforts to develop more meaningful transportation studies have resulted in general agreement that urban traffic patterns (1)* are a function of:

1. The type and extent of the transportation facilities available in an area.

2. The pattern of land use in an area, including the location and intensity of use.

3. The various social and economic characteristics of the people who make trips.

---

* Numbers in parentheses refer to items in the list of references.

As a result there has been made a significant effort to develop a transportation planning process which utilizes these interrelationships in providing quantitative information on the travel demands created by alternate land use patterns and transportation systems in any urban area. Such information can then be used by various agencies to make the decisions about when and where to make improvements in transportation networks to satisfy present and future travel demands, and to promote desirable land development patterns.

The planning process must, then, be capable of estimating within limits of acceptable accuracy, the zonal trip interchanges for the alternate land use patterns and transportations systems one might reasonably expect to develop in an area. The problem then becomes one of developing such a process. As one would expect, the information obtained from home interview origin-destination surveys coupled with information on the existing land use configuration and transportation system gives an adequate picture of the existing travel patterns in an area. However, it is the future travel demands with which we are most interested, and the present-day data must in someway be extrapolated to the future.

Studies of travel habits have led to the development of mathematical formulas or " traffic models" which can satisfactorily reproduce zonal trip interchange estimates from comprehensive home interview traffic studies. If one can estimate, within acceptable limits of accuracy, the present-day zonal interchanges, and as these interchanges are dependent upon measurable characteristics of the urban area it follows, that if one can estimate the future urban

characteristics such as intensity and type of land use, the distribution of job opportunities, and the economic status of the residents, one should be able to estimate the zonal interchanges of the future. This is subject, of course, to the possibility that, for a given set of identical circumstances for the present and the future, higher or lower trip generation rates may result because of a change in the amount of travel per vehicle. Several formulations of traffic models have been developed for the estimation of future interchanges, particularly in large metropolitan areas, but much additional research is needed to evaluate and verify the various models in cities of all sizes.

The mathematical traffic model offers to those responsible for making the decisions concerning the development of the transportation system estimates of likely consequences in terms of traffic patterns for various alternative land use configurations and transportation systems.

There are a number of different traffic models currently being utilized in transportation studies but the most widely used model to date is the so-called "gravity model." This model is based upon the adaptation of Newton's Law of gravity to the movements of human beings. Newton's Law states that the gravitational force exerted between two bodies in space is in direct proportion to the masses of the two bodies and inversely proportional to the square of the distance between the bodies.

A number of persons over the years have used Newton's Law as applied to human activities with varying degrees of success. In the middle 1800's, H. C. Carey (2) theorized that the attraction

force between two large population masses followed Newton's Law; G. K. Zipf (3), W. J. Reilly (4), and H. J. Casey (5) were among others that attempted to apply Newton's Law to human activities. In 1955, Alan Voorhees developed a gravity model theory of traffic movement in which he used the principle of Newton's Law (6).

In order to apply the gravity model theory to a given city, it generally is considered necessary to conduct, as a minimum, a comprehensive origin-destination (O-D) survey and to "calibrate" or adjust the model to reproduce, at an acceptable level, the trip distributions found in the O-D survey. The model is then used to distribute trips with various configurations of land use and transportation alternatives that one would logically expect to develop in the future.

The survey methods used to gather O-D data on present-day travel are both expensive and time consuming. Certain Iowa studies (9) (13) indicated quite graphically the savings in time and money made possible by the utilization of the Gravity Model, and also explored the feasibility of applying the gravity model to cities with a population as small as 34,000 persons. In nearly all of the previous uses of this model very large metropolitan areas were studied (10).

Purpose

This research was concerned with the use of the gravity model in a small city and was conducted to study the feasibility of using a small sample of home interviews taken in a sample of O-D zones to estimate the gravity model parameters, trip production, trip attrac-

tion and travel time factors. A gravity model was calibrated using the estimations of trip productions and attractions obtained from the small sample of O-D interviews. An additional model was calibrated using the productions and attractions obtained from the comprehensive home-interview O-D survey. The resulting distributions were compared with the distribution obtained from the comprehensive survey.

In the sample study, the information obtained from interviews from 402 dwelling units in 14 selected zones was utilized. The comprehensive O-D study consisted of 2,528 interviews obtained from a 20 per cent sample of dwelling units from all 83 zones in the survey area.

Scope

The study was limited to the consideration of auto-driver trips which were internal in nature. That is, each trip had both its origin and destination within the survey area. The survey area is shown in Figure 1.

The auto-driver trips were classified according to trip purpose. The three trip purposes of home-work, home-other and non-home-based trips were studied in detail.

The study was concerned with "present day" traffic rather than with the estimation of future traffic; however, the data used in the development of estimating equations for attractions and productions were those which one could expect to be obtained quickly and economically, and that one could expect to estimate reasonably well for the future.

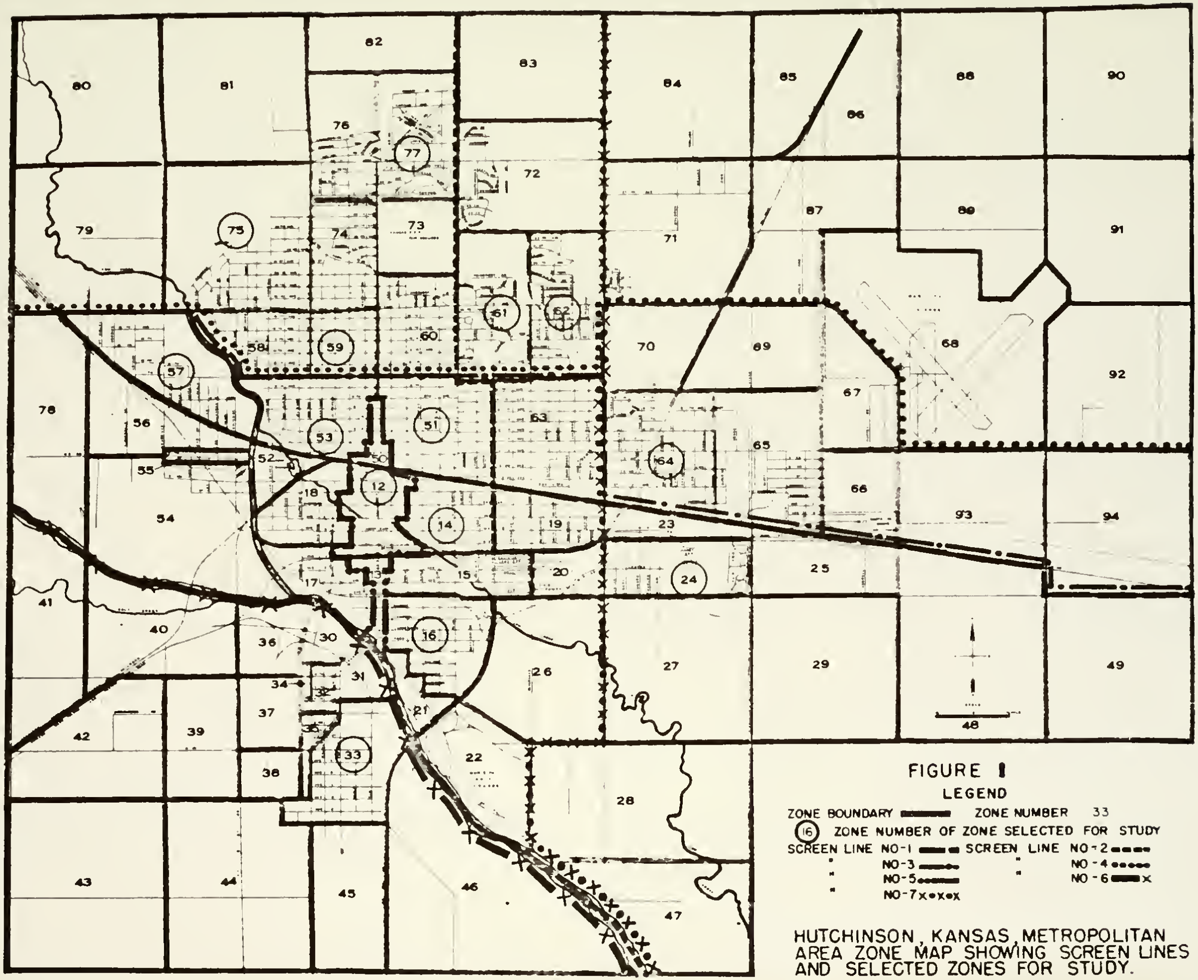


FIGURE 1

HUTCHINSON, KANSAS, METROPOLITAN AREA ZONE MAP SHOWING SCREEN LINES AND SELECTED ZONES FOR STUDY.

Gravity Model Theory and Use

The gravity model theory as proposed by Voorhees stated that the trip interchange between zones is directly proportional to the relative attraction for trips of each of the zones and inversely proportional to some function of the spatial separation between zones.

Stated mathematically, the gravity model formulation as used in its earlier applications, is shown below.

$$T_{i-j} = P_i \left[\frac{\dfrac{A_j}{(d_{i-j})^b}}{\dfrac{A_i}{(d_{i-i})^b} + \dfrac{A_j}{(d_{i-j})^b} + \cdots \dfrac{A_n}{(d_{i-n})^b}} \right]$$

Where T_{i-j} = Trips produced by zone i and attracted to zone j

P_i = Trip produced by zone i

A_j = Trips attracted by zone j

d_{i-j} = The spatial separation between zones i and j, and generally expressed as total travel time between zones i and j

b = An empirically determined exponent which expresses the average areawide effect of spatial separation between zones on the amount of trip interchange.

Early research by Voorhees and others indicated that the exponent, b, varied between 0.6 and 0.8 for work trips in areas of different population size (7). Davidson (8) found exponents of 3.5 and 5.0 most suitable for work trips and non-work trips, respectively, and the differences among exponents developed by him and those developed by Voorhees and others were explained to some extent by

differences in the manner of measuring time and distance between zones. A number of studies have indicated the need for a variable exponent and Davidson (8) found that the best exponent for near zones was different from the best exponent for distant zones.

In response to the studies indicating a need for a variable exponent and other refinements, the form of the gravity model formula was changed to the following which was used in this study:

$$T_{i-j} = \frac{P_i \; A_j \; F_{i-j} \; K_{i-j}}{\sum_{x=1}^{n} A_x \; F_{i-x} \; K_{i-x}} \qquad \text{(Equation A)}$$

in which the distribution is generally handled on a basis of various trip purposes and where:

T_{i-j} = Trips produced in zone i and attracted to zone j

P_i = Trips produced by zone i

A_j = Trips attracted by zone j

F_{i-j} = An empirically derived travel time factor which expresses the average areawide effect of spatial separation on the trip interchange between zones. The measure of distance or spatial separation between zones is usually the total travel time between the centroids of zones i and j. The use of this factor to express the effect of distance between zones upon the zonal trip interchange, rather than the previously used inverse exponential function of time, greatly simplifies the computational requirements of the model. It also provides for the consideration that the effect of spatial separation generally increases as the separation increases, particularly for some trip purposes.

K_{i-j} = A specific zone-to-zone adjustment factor to allow for the incorporation of the effect on travel patterns of defined social or economic linkages not otherwise accounted for in the gravity model formulation.

n = Total number of zones.

In dealing with the gravity model, confusion often exists among the terms productions, attractions, origins, and destinations.

With the exception of trips classified as non-home-based, the number of trips produced refers to the number of trips originating in and returning to a given zone; the number of trips attracted refers to the number of trips arriving at and departing from a given zone. The gravity model, in the determination of T_{i-j}, deals with trip interchange between zones and such interchanges do not imply the direction of movement. The trip interchange between zones is often referred to as "non-directional" or "two-way" trips as opposed to directional trips or trips which start in zone i and end in zone j. Some models use the one-way trip and deal with origins and destinations. As an illustration of the differences between trip productions and attractions consider the following example:

Figure 2a schematically represents trips made by occupants of a given dwelling unit of Zone 1, while Figure 2b represents trips made by a resident of Zone 3. The "tail" of the arrow (a trip) represents an origin, while the "head" of the arrow represents a destination.

The trips illustrated in each figure will be separated into two categories, the "home-based" and the "non-home-based" trips. Any trip in which the home is one end of the trip is classified as a home-based trip. The home-based trip may be further classified with

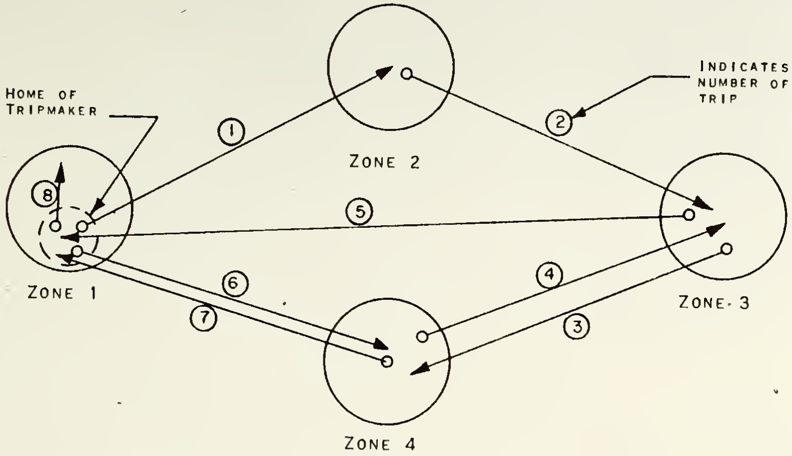


FIGURE 2a

TRIPS MADE BY ONE TRIPMAKER WHOSE ZONE OF RESIDENCE IS ZONE 1

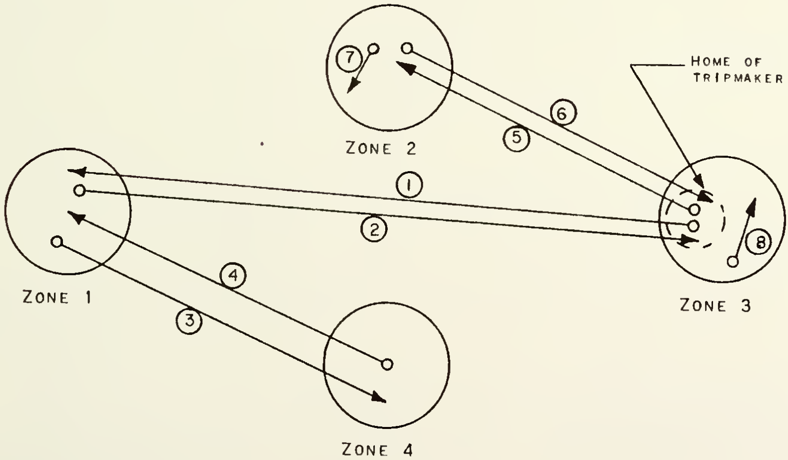


FIGURE 2b

TRIPS MADE BY ONE TRIPMAKER WHOSE ZONE OF RESIDENCE IS ZONE 3

regard to trip purpose such as work, eat meal, social, medical-dental, school, etc. Any trip in which the home is neither end of trip is classified as a non-home-based trip. In Figure 2a, trips 1, 5, 6, 7 and 8 are home-based trips while in Figure 2b trips 1, 2, 5 and 6 are home-based trips.

Trip 8 in Figure 2a, and trips 7 and 8 in Figure 2b are intra-zonal trips since both ends of the trip remain within a single zone. All other trips are interzonal trips.

In Figure 2a, Zone 1, the zone of residence of the trip maker "produces" 5 home-based trips (trip ends), and in Figure 2b, Zone 3, the zone of residence of the trip maker "produces" 4 home-based trips (trip ends). Note that in Figure 2a the origin of trip 1, the destination of trip 5, the origin of trip 6, the destination of trip 7, and the origin of trip 8 are trip "productions" and similarly, in Figure 2b, the origin of trip 1, the destination of trip 2, the origin of trip 5, and the destination of trip 6 are termed trip "productions." Note that in either Figure 2a or 2b that only those zones in which the trip maker resided were producers of home-based trips.

It follows then that for any zone to be producer of home-based trip ends there must be persons residing in that zone making trips that have one end at home.

Any end of a home-based trip which is not a "production" is said to be an "attraction". The home-based trip attractions are distributed as follows:

	Zone	No. of Attractions	Trip and End
	1	1	Destination end of trip 8
(see Figure 2a)	2	1	Destination end of trip 1
	3	1	Origin end of trip 5
	4	2	Destination end of trip 6 Origin end of trip 7
	Total =	5	

	Zone	No. of Attractions	Trip and End
	1	2	Destination end of trip 1 Origin end of trip 2
(see Figure 2b)	2	2	Destination end of trip 5 Origin end of trip 6
	3	0	
	4	0	
	Total =	4	

Consider the non-home based trips. In Figure 2a, the non-home-based trips are trips 2, 3 and 4, and in Figure 2b, they are trips 3, 4, 7 and 8. For non-home-based trips, the production end of a trip is its origin end and the attraction end is its destination.

The non-home-based trip production is distributed as follows:

	Zone	No. of Productions	Trip and End
	1	0	
(see Figure 2a)	2	1	Origin end of trip 2
	3	1	Origin end of trip 3
	4	1	Origin end of trip 4
	Total =	3	
	1	1	Origin end of trip 3
(see Figure 2b)	2	1	Origin end of trip 7
	3	1	Origin end of trip 8
	4	1	Origin end of trip 4
	Total =	4	

The non-home-based attractions are distributed as follows:

	Zone	No. of Attractions	Trip and End
	1	0	
(see Figure 2a)	2	0	
	3	2	(Destination of trip 2 (Destination of trip 4
	4	1	Destination of trip 3
		Total = 3	
	1	1	Destination end of trip 4
(see Figure 2b)	2	1	Destination end of trip 7
	3	1	Destination end of trip 8
	4	1	Destination end of trip 3
		Total = 4	

Note that there are always as many productions as attractions on a total study area basis since each trip has two ends.

If one would superimpose Figure 2a upon Figure 2b, the gross effect would be that of having considered trips by persons residing in both Zones 1 and 3. If all internal trips by all residents of the zones were recorded, total trip productions and attractions could be determined. If one would interview each resident of Zone 1 and determine the trips produced and attracted to each of the four zones for both home-based and non-home-based trips, one would have the following information:

(a) The total number of trip productions that would be said to be produced by Zone 1. (This number would correspond to P_i in the gravity model formula.)

(b) The number of home-based trip attractions in each zone would correspond only to the dis-distribution of the attraction ends of trips produced by the residents of Zone 1.
The non-home-based attractions and productions, likewise, would correspond only to the distribution of the non-home-based trips "made" by the residents of Zone 1.

It follows, then, that to obtain the total number of home-based attractions, or non-home-based productions or attractions in a given zone the universe of all the population of all zones must be interviewed or sampled while the total number of home-based productions of a given zone can be obtained by interviewing or sampling from that particular zone.

Figure 3 shows a schematic diagram of the process of determining zonal trip productions and attractions.

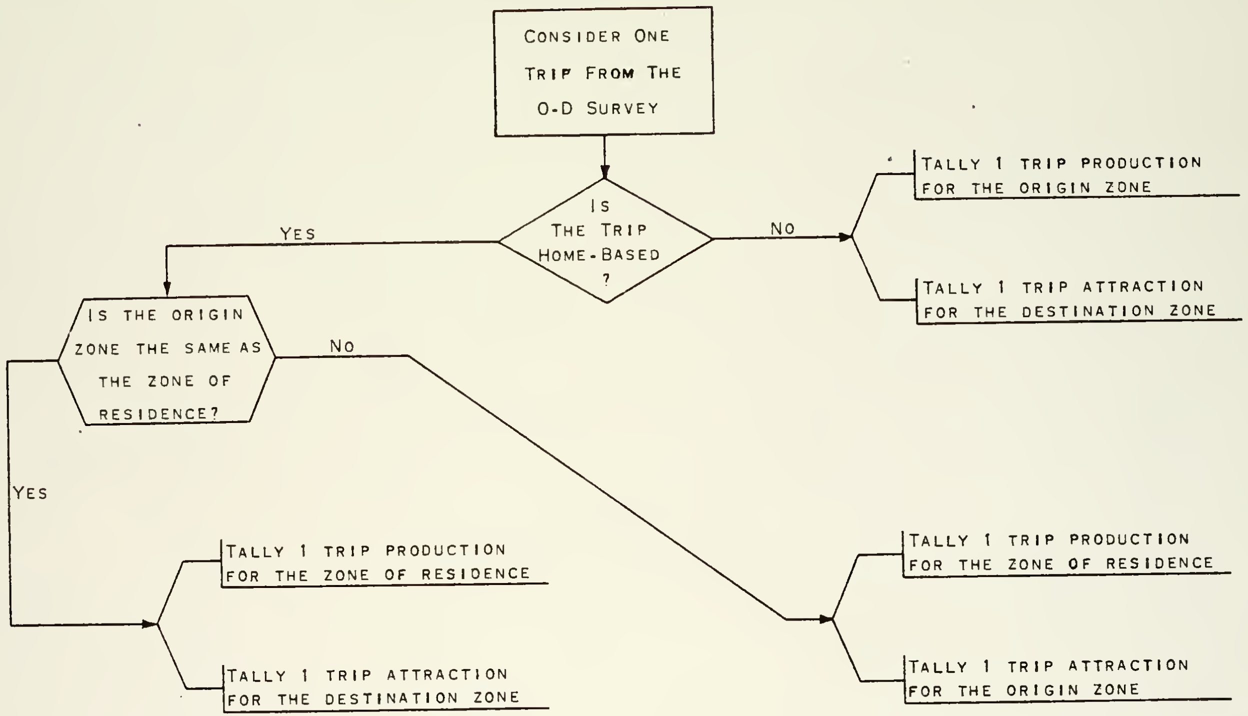


FIGURE 3

SCHEMATIC DIAGRAM OF THE PROCESS OF
DETERMINING ZONAL TRIP PRODUCTIONS AND ATTRACTIONS

STUDY PROCEDURE

In order to carry out the objectives of the research, the metropolitan area of Hutchinson, Kansas was chosen for the study. The City, in 1961, had a population of 37,873 while the metropolitan area had a population of approximately 41,000 persons. At the initiation of this project this was the only "smaller" city in Kansas in which both an internal origin-destination survey as well as a land use study had been made. The Pittsburg, Kansas Transportation Study was completed in the summer of 1963. Origin-destination and some land use data were available for Topeka, Wichita and Kansas City, Kansas. These were the three largest metropolitan areas in Kansas and were not typical in size of "smaller" Kansas Cities. Table 1 indicates all cities in Kansas with a population over 10,000. There were 24 cities, outside of metropolitan areas, with a population between 10,000 and 50,000, and only 3 cities with a population over 50,000. It was believed that the results of the study, if aimed at such smaller cities, would be of greatest value in Kansas since the smaller cities so outnumber the larger metropolitan areas.

In 1959, the Kansas State Highway Planning Department, in cooperation with the Bureau of Public Roads and the City of Hutchinson, conducted a comprehensive home interview O-D survey and a complete land use study in the Hutchinson Metropolitan Area. The O-D survey was conducted in accordance with standard procedures pre-

TABLE 1

CITIES OF KANSAS HAVING POPULATION OVER 10,000*

City	Population
Wichita	247,557
**Kansas City	126,236
Topeka	120,799
Salina	43,090
**Overland Park	40,796
Hutchinson	37,873
**Prairie Village	26,873
Lawrence	26,132
Leavenworth	23,707
Manhattan	21,410
Junction City	20,944
Pittsburg	18,737
Great Bend	17,885
Coffeyville	17,030
Emporia	16,763
Liberal	14,806
Newton	14,704
Arkansas City	14,696
Dodge City	13,303
Parsons	13,014
El Dorado	12,614
Garden City	12,575
Hays	12,301
Atchison	12,126
Independence	11,387
**Shawnee	11,387
Ottawa	11,237
Olathe	10,776
Chanute	10,666
Winfield	10,522

* Populations as of January 1, 1962 as reported by county assessors and compiled by the Kansas State Board of Agriculture.

** Included within Kansas City, Kansas Metropolitan Area.

scribed by the Bureau of Public Roads. The internal survey was made by the home-interview method in which a 1 in 5 (20 per cent) dwelling unit sample was taken. The data gathered in the internal O-D survey and the land use study were used in this research.

Among the data collected for each surveyed dwelling unit in the internal O-D survey were the following:

Number of persons
Number of employed persons
Number of cars owned
Age groups
Number of vehicular trips
Trip purposes at origins and destinations
Mode of travel for each trip

The land use study recorded the following major groupings of land use by zone in 1000's of square feet:

Residential
Manufacturing
Retail trade
Wholesale and warehouse
Transportation
Construction
Personal, business, repair services and office
Government and utility
Other open space -- streets, alleys, rivers, lakes, etc.
Recreation and institution

Appendix A shows the land use categories recorded within each major grouping.

The research was carried out in the following steps:

1. The preparation of O-D survey data for use in the research.
2. The selection of zones for use in the sample study.
3. The development of equations for estimating zonal productions.
4. The selection of samples in the 14 zones.
5. The development of equations for estimating zonal attractions.
6. The development of travel time factors.
7. The analysis of the study results.

Preparation of O-D Survey Data for Use in the Research

The information obtained from the internal O-D survey (hereafter referred to as the O-D data or O-D survey data) was, for the most part transferred to tabulating machine punch cards and was available to the researcher from the beginning of the research project. The cards were of two general types: Card 1, referred to as the dwelling unit card (only one Card 1 existed per sampled dwelling), contained information on the zone in which the dwelling unit was located, the number of cars owned by persons living in the dwelling unit, the number of persons living in the dwelling unit and information on the number of trips made on the day (the trip day) prior to the interview. Card 2, referred to as the trip card, contained information on the location zone of the home (or dwelling unit), the zone of origin of the trip, the zone of destination of the trip, the land use category at both destination and origin of the trip, mode of travel, the number of persons in the car and the purpose of travel of each end of the trip. There was a Card 2 for each trip recorded at a sampled dwelling unit.

Classification of Trips by Purpose

In most model studies the trips have been studied by grouping them into a number of trip purposes. After studying the O-D survey data, initially it was decided that the five trip-purpose groupings; home-miscellaneous and non-home, would be studied instead of the following O-D survey trip-purpose categories:

Work	Change travel mode
Business	Eat meal
Medical-dental	Shopping
School	Home
Social-recreation	Serve passenger

In an origin-destination survey, one trip ends and another begins every time a person changes his mode of travel, an auto-driver stops to serve a passenger, or when the trip-maker reaches a destination. In the first two cases, if each of these trips were analyzed separately, the relationships among the actual starting point, the destination and the purpose of trip would be lost. It would also be difficult to relate the type and intensity of trip making to the type and intensity of land use. Consequently, it is desirable to combine or link those trips which have a "change travel mode" or "serve passenger" purpose so that the relationship between the purpose of the trip and the destination of the trip is preserved. Suppose, for example, that an auto-driver drives his car from his home to the home of a co-worker where he picks up his co-worker and they both proceed to work. In this case, the auto driver's travel would be recorded as two separate auto-driver trips, the first one from "home" to "serve passenger" and the second one from "serve passenger" to "work". Since the auto-driver's purpose was to get to work, it is desirable for analysis purposes to "link" the two trip records into one which covers the entire journey. In this case, the auto-driver's "linked" trip would become a "home to work" trip by automobile. Similar reasoning could be used on travel involving change of travel mode.

Trip linking may not be necessary in all cases. In many small cities where "change travel mode" trips may be small in number because of lack of transit facilities and where "serve passenger" trips may also be small in number because of the absence of car poolings, trip linking may be unnecessary (12). However, in studying the Hutchinson data it was found that although "change travel mode" trips were negligible, the "serve passenger" trips made up approximately 23 per cent of all auto driver trips. It was, then, considered necessary to link these trips. The linking was accomplished by hand rather than with an electronic computer. In this case, it was judged to be more expedient to "hand" link than to prepare a computer program for the process. Trip linking in a large metropolitan survey area would, no doubt, be most efficiently carried out by the use of a high speed computer. The Bureau of Public Roads, in fact, has such a "trip linking" program for use on the IBM 1401 (12).

In the linking process for Hutchinson about 2,400 "trips" were lost. That is, there were 2,400 trips that made up a part of a journey with such trips not being meaningful to the major trip purpose. With the "serve passenger" trips linked or converted into meaningful purposes, the original ten trip purposes were combined into five trip purpose categories. Eventually it was found, because of the small numbers involved, to be more satisfactory to use only three trip purpose categories.

Two general classifications of trips are usually made because of differences in treatment of trip productions and attractions, and

Two general classifications of trips are usually made because of differences in treatment of trip productions and attractions, and because of the numbers of trips involved. They are, first, the trips in which one end of the trip is the home (home-based trips) and, second, the remaining trips in which neither end is the home (the non-home-based trips). Table 2 and Table 3 indicate that the major purposes of home-based trips were:

Work
Shopping
Social-recreation

Using these three categories for home-based trips and combining all other home-based trips into one category, and all non-home-based trips into another category resulted in five trip purpose groups with percentages of trips in each group as shown in Table 4. During the process of developing estimating equations for trip productions and attractions, as well as in the calibration of the model by purpose, the relatively small numbers of trips in the home-based social-recreation, shopping and miscellaneous trips appeared to be responsible for much of the variability of results being obtained. In view of this, the trip purpose groups were further combined as shown in Table 5. The discussions throughout the remainder of this report relate to the three trip-purpose groups, home-work, home-other, and non-home trips as shown in Table 5.

TABLE 2

AUTO DRIVER TRIPS BY RESIDENTS OF INTERNAL AREA, SHOWING O-D SURVEY RECORDED PURPOSE OF TRIP

From	To	(1) Work	(2) Business	(3) Medical-Dental	(4) School	(5) Social Recreation	(6) Change Travel Mode	(7) Eat Meal	(8) Shopping	(0) Home	Total
Work	(1)	2,497	615	51	128	593	21	2,609	802	8,788	16,104
Business	(2)	656	903	31	51	394	5	57	742	1,861	4,700
Medical-Dental	(3)	31	31	5	5	52	-	10	127	295	556
School	(4)	432	77	20	167	233	-	259	148	1,879	3,215
Social Recreation	(5)	422	252	26	66	1,505	16	103	736	5,678	8,804
Change Travel Mode	(6)	31	10	5	-	21	-	5	31	97	200
Eat Meal	(7)	2,446	73	15	217	140	-	5	107	352	3,355
Shopping	(8)	328	468	31	98	640	10	114	1,685	5,813	9,187
Home	(0)	9,395	2,226	387	2,523	5,332	128	339	4,786	5	25,121
Total		16,238	4,655	571	3,255	8,910	180	3,501	9,164	24,768	71,242

TABLE 3

PERCENT AUTO DRIVER TRIPS BY RESIDENTS OF INTERNAL AREA, SHOWING O-D SURVEY RECORDED PURPOSE OF TRIP

From / To		(1) Work	(2) Business	(3) Medical-Dental	(4) School	(5) Social Recreation	(6) Change Travel Mode	(7) Eat Meal	(8) Shopping	(0) Home	Total
Work	(1)	3.51	0.86	0.07	0.18	0.83	0.03	3.66	1.13	12.34	22.61
Business	(2)	0.92	1.27	0.04	0.07	0.55	0.01	0.08	1.04	2.61	6.59
Medical-Dental	(3)	0.04	0.04	0.01	0.01	0.07	0	0.01	0.18	0.41	0.77
School	(4)	0.61	0.11	0.03	0.23	0.33	0	0.36	0.21	2.64	4.52
Social Recreation	(5)	0.59	0.35	0.04	0.10	2.11	0.02	0.14	1.03	7.97	12.35
Change Travel Mode	(6)	0.04	0.01	0.01	0	0.03	0	0.01	0.04	0.14	0.28
Eat Meal	(7)	3.43	0.10	0.02	0.30	0.20	0	0.01	0.15	0.49	4.70
Shopping	(8)	0.46	0.66	0.04	0.14	0.90	0.01	0.16	2.37	8.16	12.90
Home	(0)	13.19	3.12	0.54	3.54	7.48	0.18	0.48	6.72	0.01	35.26
Total		22.79	6.52	0.80	4.57	12.50	0.25	4.91	12.87	34.77	

TABLE 4

AUTO DRIVER TRIPS - BY PURPOSE OF TRIP* (INITIAL)

	Number of Trips	Percent of Trips	Trip Purpose Code for the Study
Home - Work	18,183	25.53	0
Home - Social-Recreation	11,010	15.45	1
Home - Shopping	10,599	14.88	2
Home - Miscellaneous**	10,092	14.16	3
Non - Home	21,358	29.98	4
TOTAL	71,242	100	

* Initial trip-purpose categories for the study.
** Includes home - business, medical-dental, school, change travel mode and eat meal.

TABLE 5

AUTO DRIVER TRIPS - BY PURPOSE OF TRIP*

	Number of Trips	Percent of Trips	Trip Purpose Code for the Study
Home - Work	18,183	25.53	0
Home - Other**	31,701	44.49	9
Non - Home	21,358	29.98	4
TOTAL	71,242	100	

* Final trip-purpose categories for the study.
** Includes home - social-recreation, shopping and miscellaneous.

Additional Data Obtained

The number of employed persons per dwelling unit was determined from the home interview sheets and was placed in each dwelling unit card. Persons classified as non-gainfully employed workers, which included housewives and other unpaid home workers, retired workers, persons permanently incapacitated for any gainful employment and students were not included in the employed persons totals.

The net area of residential land use per dwelling unit was obtained and was placed in each dwelling unit card. This was determined in the following manner: The area of residential land in a given zone less the vacant land zoned residential was divided by the number of dwelling units in the zone. The area was recorded in 1000's of square feet per dwelling unit.

The driving time from the centroid of each zone to the Central Business District (CBD) was determined to the nearest 0.1 minute from the time-trees developed from a travel-time study in Hutchinson.

Prior to the development of estimating equations for work trip attractions, it was decided, as was found in an Iowa study (9), that the number of jobs in a zone would be expected to be a potent indicator of home-work trip attractions. Information on various categories of employment in each zone was therefore collected. An attempt was made to determine the employment in the various zones as it existed at the time the O-D survey was made, but it was possible to determine only major changes in employment. A very good correlation, however, of total number of jobs in the survey area with

the 1960 Census data was obtained.

The employment study was made in the Hutchinson Office of the Kansas State Employment Service. Due to the excellent cooperation of the employment service personnel, the survey was completed within three days with two persons collecting most of the data. The number of employees in each of the ten types of business and industry listed below, and the number of self-employed persons were tabulated by zone.

Type of industry or business

- Agriculture - forestry
- Mining
- Construction
- Manufacturing and processing
- Transportation, communications and public utilities
- Wholesale, retail, finance, insurance
- Personal services
- Amusement recreation
- Professional
- Government

Selection of Zones for use in the Reduced Sample Study

Zones were selected for the reduced sample survey so that they would reflect a range in such zonal characteristics as residential density, car ownership rate, population density, distance from the central business district and distance to the nearest large employment center. An investigation of the Hutchinson data showed that the principal CBD zone, 12, was, in fact, the large employment center in the city. A zonal map (Figure 1) was used in selecting the zones. For each zone having any significant number of dwelling units, the number of dwelling units, cars owned by residents of the zone, total number

of persons residing in the zone, cars per dwelling unit, and persons per dwelling unit were noted on a zone map.

The selection of zones was further based upon opinions of those familiar with the nature of residential areas in Hutchinson such that zones of varying economic status or value of residence would be chosen.

Zones 12, 16, 33, 51, 64, 75, and 77 were chosen for initial study; however, in the analysis concerning the estimation of trip productions and attractions, it was found that seven zones were inadequate for the intended use. Additional zones 14, 24, 53, 57, 59, 61, and 62 were chosen for the remaining analysis.

Pertinent data on all zones, as well as the fourteen selected zones, are shown in Table 6. In Table 6, the numbers in the column titled "Total Dwelling Units" were obtained by multiplying the number of sample dwelling units within a zone by the dwelling unit factor (D. U. F.) for that zone. A sample dwelling unit was taken as any dwelling unit in which an interview was intended to be made. Thus, vacant dwelling units, dwelling units in which residents refused to answer questions, dwelling units in which no one was found at home or in which contagious sickness was found, and dwelling units in which survey questions were answered comprised the total of sample dwelling units in a given zone.

The dwelling unit factor for each zone was calculated as follows:

$$\text{D. U. F.} = \frac{A - \left(\frac{CA}{B}\right)}{B - (C + D)}$$

where

A = Total number of addresses in the zone

B = Total number of addresses, in the zone, initially selected as sample dwelling units

C = The sum of sample dwellings within the zone found to be vacant, demolished or used for commercial purposes only

D = The sum of interviews within the zone "missed" because of contagious sickness in the household, no one found at home or residents refused to answer questions.

Note: When "D" is zero, D. U. F. $= \frac{A}{B}$.

The numbers in the column, in Table 6, titled "Dwelling Units"* were obtained by multiplying, for each zone, the dwelling unit factor by the number of sample dwellings in which answers to the survey questions were obtained.

The Development of Equations for Estimating Zonal Productions

Early attempts were made to develop estimating equations based upon groups of samples within each of the seven initially selected zones. It was hoped that interviews obtained in a single zone could be grouped into small subsamples that would give good estimates of the productions and attractions of that particular zone.

Information concerning the assessed evaluation per dwelling unit in Zone 75 (see Figure 1) was obtained in a two-day study of the city records in Hutchinson. The "evaluation" data were tested for value as an "economic" indicator in the production of trips. The results were inconclusive since the trip production based upon the sub-

TABLE 6

ZONAL CHARACTERISTICS

Expanded Sample Data							
Zone	Total Dwelling Units	Dwelling Units*	Total Cars Owned	Total Persons	CBD Distance (Min.)	Area/DU (Sq. Ft.)	Total Jobs
12**	293	245	156	341	0.5	2300	5000
13	66	51	36	143	2.0	6110	614
14**	754	656	588	1695	1.4	5402	361
15	337	271	224	975	2.9	8601	32
16**	434	393	374	1343	4.3	8602	197
17	164	118	72	398	2.7	8710	169
18	541	453	325	1410	1.7	6403	615
19	464	422	457	1398	2.9	7797	175
20	-	-	-	-	4.1	-	72
21	-	-	-	-	5.6	-	9
22	-	-	-	-	6.2	-	3
23	15	15	15	26	5.5	6140	226
24**	270	250	347	864	5.7	11301	21
25	-	-	-	-	10.1	12500	171
26	-	-	-	-	5.5	12500	-
27	40	40	60	134	7.7	16380	19
28	25	25	35	114	8.3	15450	4
29	5	5	5	10	10.6	12500	4
30	-	-	-	-	3.0	-	45
31	-	-	-	-	4.2	-	90
32	55	55	70	174	3.9	11150	73
33**	298	284	358	1080	5.7	13799	56
34	5	5	5	15	3.9	12500	127
35	35	20	15	61	4.6	23350	130
36	41	31	41	81	4.3	2610	15
37	5	-	-	-	4.6	-	-
38	-	-	-	-	5.3	-	5
39	41	41	56	132	6.4	22280	12
40	10	10	10	36	6.0	12500	184
41	-	-	-	-	12.0	-	3
42	81	81	132	234	7.7	34560	11
43	15	15	10	36	9.4	12500	4
44	10	10	15	41	7.8	12500	4
45	46	46	66	178	7.4	14950	6
46	5	5	15	20	8.6	12500	-
47	-	-	-	-	10.7	-	-
48	5	5	5	30	12.6	12500	-
49	-	-	-	-	14.0	-	-
50	117	100	58	144	1.6	1630	1150
51**	1472	1244	1236	3573	2.9	1126	766
52	32	27	21	112	3.3	7850	100
53**	966	850	778	2319	3.3	5799	437

TABLE 6 (Cont.)

Expanded Sample Data							
Zone	Total Dwelling Units	Dwelling Units*	Total Cars Owned	Total Persons	CBD Distance (Min.)	Area/DU (Sq. Ft.)	Total Jobs
54	133	112	138	401	3.9	12460	-
55	32	32	48	70	3.9	17410	146
56	94	94	125	324	6.1	16460	153
57**	313	275	349	840	5.9	13601	99
58	534	493	567	1414	5.2	10002	65
59**	603	540	551	1576	4.3	5701	166
60	861	824	1021	2387	5.0	1311	190
61**	357	292	402	986	6.3	7799	251
62**	413	384	454	1524	7.4	10302	61
63	1163	1074	1151	3470	4.5	2969	513
64**	574	539	575	1781	5.8	1775	155
65	90	74	96	265	7.7	7500	604
66	-	-	-	-	8.8	-	809
67	64	60	79	243	9.7	29130	50
68	-	-	-	-	11.1	-	85
69	-	-	-	-	9.2	-	62
70	-	-	-	-	6.8	-	-
71	171	144	203	621	11.2	37620	17
72	91	81	111	258	8.7	13500	69
73	-	-	-	-	6.4	-	234
74	655	620	855	1890	6.2	1835	123
75**	698	641	854	2157	6.7	1153	163
76	258	243	400	869	7.3	15298	78
77**	495	464	676	1471	7.3	5188	76
78	31	31	87	102	6.8	36970	13
79	31	31	61	92	8.7	26670	18
80	5	5	5	19	12.1	12500	3
81	14	14	19	38	10.8	12500	11
82	-	-	-	-	11.6	-	1
83	10	10	10	46	11.7	12500	7
84	67	67	87	256	12.8	18880	7
85	46	46	82	200	12.6	32790	84
86	-	-	-	-	11.5	-	19
87	55	55	89	188	10.7	20710	59
88	5	5	10	31	14.9	12500	-
89	10	10	15	30	14.9	12500	1
90	-	-	-	-	16.9	-	-
91	-	-	-	-	16.2	-	2
92	25	25	30	94	13.6	12500	9
93	5	5	10	35	12.0	12500	6
94	15	15	15	69	13.6	12500	15

* No. Dwelling Units Answering Survey Questions x Dwelling Unit Factor

** Indicates 14 selected zones

samples showed such a great amount of variability. Examination of the evaluation study indicated that such a study for each zone in the area would probably not produce data that would be of significant aid in the estimation of zonal trip productions and attractions. It was also believed that the number of "employed persons per dwelling unit" might be a better indicator of work trip production than "persons per dwelling unit." In order to test this hypothesis, four sets of regression equations were developed using, among the variables, either "persons per dwelling unit" or "employed persons per dwelling unit". The data used were from the comprehensive survey for the 22 zones which contained more than 125 dwelling units. There was less than one per cent difference between the value of R^2, the coefficient of determination, for each pair of equations. It was concluded, therefore, that "employed persons per dwelling unit" was no better indicator of work trip production than was "persons per dwelling unit".

Due to the great variability among subsamples as well as the problems anticipated in gathering data on zonal characteristics in such small areas, the estimation of productions was carried out using zonal averages of such information as cars and persons per dwelling unit, area of residential land per dwelling unit and distance to the CBD in minutes. The development of the estimating equations was carried out using the multiple regression technique in which the form of an equation is estimated and the coefficient of each term is obtained from the "least squares" best fitting curve. The measure of fit was obtained as an output of the computer program used (13).

The SCRAP "Sixteen-twenty Card Regression Analysis Program," used in this research, is one of a number of such programs available in most computing centers. It became apparent early in the investigation that, for productions, as many as seven terms would probably be required in the estimating equation. Seven zones would give only seven pieces of data and the computer program, in essence, was able to pass a curve through each point represented by the data. This situation does not allow one to predict, statistically, the goodness of fit of the estimating equation to other zones one might consider. After consultation with statisticians, it was decided that a minimum of 14 zones (7 additional zones) would be required if a 7-term estimating equation were to be used. Data from 14 zones, giving 14 pieces of information, were judged to give a satisfactory statistical estimate of the "predictive" power of the estimating equation. A minimum of seven degrees of freedom was judged to be required.

Two sets of estimating equations of trip production were developed. One was based upon zonal characteristics obtained from each of 22 zones as a result of sampling 20 per cent of the dwelling unites in each zone. The 22 zones were those zones in which over 25 dwelling units were sampled. In essence, the 22 zones represented the universe of zones which were of substantial size.

The second set of equations was based upon zonal characteristics obtained from each of the previously mentioned 14 selected zones. However, in this case, a sampling rate was established for each zone.

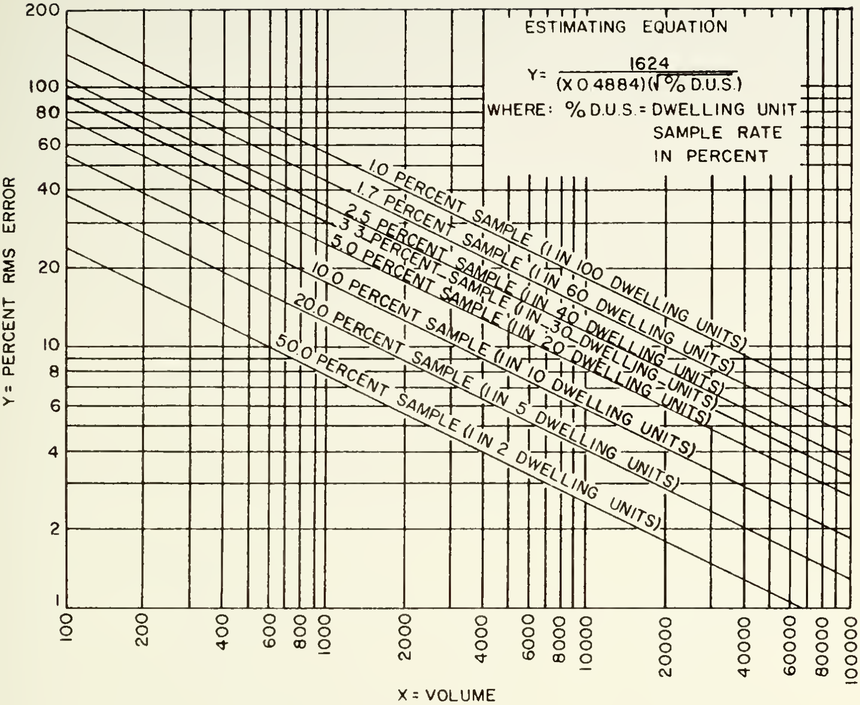
In order that the total number of non-home-based trip productions could be estimated, non-home-based trips were treated precisely as home-based trips. These "productions" represented only the number of non-home trips made by the residents of each zone and did not distribute the trips according to location of trip end. A regression analysis, similar to the analysis used for home-based productions, was made on these trips with the resulting equation, as expanded to the entire area, giving the total number of non-home trip productions or attractions. This number was later used in expanding the non-home-based productions to this estimated total (see the discussion concerning estimation of non-home productions and attractions).

Selection of Reduced Samples

The selection of the reduced sample size in the 14 selected zones was made in accordance with research conducted by Sosslau and Brokke for the Bureau of Public Roads (14).

In order to use Figure 4, it is necessary to estimate the number of trips per zone and to select a root-mean-square (RMS) error that is acceptable. One can then enter Figure 4 and select the appropriate rate of sampling.

A level of accuracy yielding an expected RMS error of zonal trip production of fifteen per cent or less was agreed as acceptable. The estimation of trips produced per zone was made and, in this case, the city wide average was about five auto-driver trips per dwelling unit. Where an estimate of this average is not available for a city, studies of trip making characteristics of similar cities should



For rates not plotted, the following equation can be used:

$$\text{Dwelling-unit sample rate in percent} = \left[\frac{1.624}{(\text{percent RMS error})\,(\text{volume}^{0.4884})}\right]^2$$

FIGURE 4*

RELATION OF PERCENT ROOT-MEAN-SQUARE ERROR AND VOLUME FOR VARIOUS DWELLING UNIT SAMPLE RATES

*Source: Reference (14)

suffice for this estimate.

Figure 4 was entered with X, the estimated volume of trips in a given zone, and the 15 per cent RMS error line indicated the minimum percentage of dwelling units to be sampled in that zone. The subsample was drawn from the O-D sample and was selected by a computer program.

The subsample in Zone 12 was selected as follows:

1. Estimated Trips = 5 × 270 dwelling units = 1,350.

2. Enter Figure 4 with 1,350 and intersect the horizontal 15 per cent RMS error line.

3. Read 15± per cent sample.

4. A 15 per cent sample is equivalent to 3/4 of a 20 per cent sample (the existing sample size).

5. The computer program was devised to select the dwelling unit and trip cards for every n^{th} sampled dwelling unit and in this case a random selection of a number from 1 to 4 was made to indicate the starting sample and thereafter every fourth "dwelling unit" sample was selected. This group was discarded and the remaining 3/4 of the original 20 per cent sample was taken. The original expansion factors were multiplied by the ratio of the original number of sampled dwelling units to the reduced number of sampled dwelling units and this new expansion factor was placed in the dwelling unit and trip cards for the "reduced samples".

Table 7 shows the sample size selected in each of the 14 zones.

Tables 8 and 9 show zonal characteristics for the 14 zones for the full as well as the reduced sample, respectively.

Tables 10 and 11 show the trip attractions and non-home productions per trip produced for the 14 zones for the full as well as the reduced sample, respectively.

TABLE 7

REDUCED SAMPLE SELECTION IN THE 14 SELECTED ZONES

Zone	Estimated* auto driver trips per zone (1)	% Sample size to obtain 15% RMS error (2)	Fraction of original 20% sample (3)	Number of interviews selected (4)	O-D expansion factor (5)	Number of dwelling units in original sample (6)	Expansion** factor for reduced sample (7)
12	1,350	15	3/4	35	5.32	46	6.99
14	3,760	5	1/4	32	5.21	126	20.51
16	2,160	7	1/3	25	5.11	77	15.74
24	1,350	11	1/2	24	5.11	49	10.43
33	1,490	10	1/2	29	4.98	57	9.79
51	7,360	2.5	1/8	29	5.34	233	42.90
53	4,820	3.3	1/6	27	5.18	164	31.46
57	1,570	10	1/2	26	5.19	53	10.58
59	3,010	5	1/4	26	5.29	102	20.75
61	1,785	9	1/2	29	5.03	58	10.06
62	2,060	7	1/3	25	5.05	76	15.35
64	2,870	6	1/3	35	5.13	105	15.39
65	3,490	5	1/4	30	5.21	123	21.36
77	2,470	7	1/3	30	5.16	90	15.48
Total				402			

* 5x Number of dwelling units per zone (See table 6 for dwelling units per zones)

** Col. (5) x $\frac{\text{Col. (6)}}{\text{Col. (4)}}$

TABLE 8

ZONAL CHARACTERISTICS USED FOR TRIP PRODUCTION ESTIMATES
DATA FROM O-D FULL SAMPLE IN THE 14 SELECTED ZONES

Zone	Cars Per Dwelling Unit	Persons Per Dwelling Unit	Trips Per Dwelling Unit Home-Work	Home-Other	Non-Home*
12	.630	1.391	.283	1.130	.609
14	.905	2.660	1.342	2.025	1.048
16	.948	3.416	1.351	2.182	1.325
24	1.388	3.449	1.735	3.204	2.000
33	1.241	3.741	1.655	3.414	1.948
51	.986	2.844	1.174	1.965	1.008
53	.891	2.685	1.254	1.473	.673
57	1.245	3.000	1.453	2.171	1.566
59	1.039	2.932	1.398	2.049	.981
61	1.379	3.379	1.879	3.103	2.741
62	1.184	3.974	1.553	2.750	2.698
64	1.047	3.256	1.361	2.114	1.095
75	1.322	3.337	1.435	2.555	2.813
77	1.455	3.166	1.844	4.211	3.155

* Used only for estimation of total non-home trips produced in the metropolitan study area.

TABLE 9

ZONAL CHARACTERISTICS USED FOR TRIP PRODUCTION ESTIMATES
DATA FROM O-D REDUCED SAMPLE IN THE 14 SELECTED ZONES

Zone	Cars Per Dwelling Unit	Persons Per Dwelling Unit	Trips Per Dwelling Unit: Home-Work	Home-Other	Non-Home*
12	.629	1.371	.229	1.057	.486
14	.781	2.406	1.063	1.188	.438
16	.960	2.920	1.480	1.600	1.440
24	1.500	3.542	1.583	3.708	2.047
33	1.207	3.965	2.103	3.000	1.758
51	1.172	2.758	1.138	1.966	.828
53	.963	2.630	1.259	1.816	.741
57	1.038	2.923	1.115	2.462	1.846
59	1.000	2.885	1.385	2.930	1.115
61	1.276	3.207	1.827	2.551	3.600
62	1.160	4.200	1.920	2.560	2.342
64	.943	3.000	1.371	1.571	1.029
75	1.300	2.933	1.433	2.833	3.066
77	1.567	3.366	1.800	5.200	4.566

* Used only for estimation of total non-home trips produced in the metropolitan study area.

TABLE 10

TRIP ATTRACTIONS AND NON - HOME PRODUCTIONS FROM O-D FULL SAMPLE DATA FROM THE 14 SELECTED ZONES

Zone	Trip Attractions per Trip Produced			Trip Production per Trip Produced
	Home - Work	Home - Other	Non - Home	Non - Home
12	.319	.196	.252	.273
13	.037	.014	.024	.027
14	.028	.029	.038	.037
15	---	.009	.005	.003
16	.010	.015	.011	.013
17	.008	---	.001	.002
18	.050	.015	.040	.041
19	.016	.018	.015	.014
20	.009	.001	.001	---
21	.001	.009	.002	.003
22	---	.002	.001	.001
23	.013	.002	.002	.004
24	.003	.006	.011	.008
25	.010	---	.002	.004
26	.001	---	---	---
27	.001	---	---	---
28	.001	---	---	---
29	---	---	---	---
30	.004	.001	.002	.002
31	.008	.004	.002	.003
32	.004	.003	.005	.004
33	.005	.020	.011	.014
34	.009	.024	.013	.014
35	.006	.007	.006	.006
36	---	---	---	---
37	---	---	---	---
38	.001	.004	---	---
39	---	.001	---	---
40	.013	---	.001	---
41	---	---	---	---
42	---	---	---	.001
43	---	---	---	---
44	---	---	---	---
45	---	.001	.002	.001
46	---	---	---	---
47	.001	---	---	---
48	---	---	---	---
49	---	---	---	---
50	.074	.092	.077	.087
51	.059	.083	.078	.072
52	.006	.003	.004	.004
53	.028	.063	.062	.052

TABLE 10 (Continued)

Zone	Trip Attractions per Trip Produced			Trip Production per Trip Produced
	Home - Work	Home - Other	Non - Home	Non - Home
54	.001	.003	.002	.001
55	.012	.002	.005	.005
56	.010	.003	.003	.003
57	.004	.008	.013	.012
58	.004	.010	.009	.007
59	.013	.036	.027	.025
60	.014	.052	.028	.025
61	.025	.044	.027	.031
62	.004	.010	.021	.020
63	.027	.060	.046	.034
64	.010	.023	.019	.019
65	.036	.006	.013	.015
66	.043	.001	.005	.008
67	.004	---	.002	.003
68	.003	.003	.004	.005
69	---	---	---	---
70	---	---	---	---
71	.002	.003	.002	.001
72	.011	.005	.005	.004
73	.014	.023	.011	.014
74	.006	.019	.014	.013
75	.013	.016	.028	.023
76	.004	.016	.005	.007
77	.006	.023	.032	.027
78	---	.003	---	---
79	---	---	---	---
80	---	---	---	---
81	.001	.001	.001	.001
82	---	---	---	---
83	.001	.---	---	---
84	---	.002	.001	---
85	.004	.003	.002	.001
86	.002	.001	---	---
87	.004	.001	.001	.001
88	---	.001	.001	.001
89	---	---	---	---
90	---	---	---	---
91	---	---	---	---
92	---	---	---	---
93	---	---	---	---
94	---	---	---	---

TABLE 11

TRIP ATTRACTIONS AND NON - HOME PRODUCTIONS FROM
O-D REDUCED SAMPLE DATA FROM THE 14 SELECTED ZONES

Zone	Trip Attractions per Trip Produced			Trip Production per Trip Produced
	Home - Work	Home - Other	Non - Home	Non - Home
12	.368	.215	.282	.313
13	.034	.007	.025	.030
14	.030	.024	.025	.028
15	---	.006	.005	.002
16	.005	.004	.008	.014
17	.006	---	.001	.003
18	.051	.008	.034	.034
19	.016	.008	.013	.009
20	.015	---	.002	---
21	---	.005	---	.001
22	---	---	.002	.002
23	.022	.007	.005	.005
24	---	.004	.008	.007
25	.003	---	---	.001
26	---	---	---	---
27	---	---	---	---
28	---	---	---	---
29	---	---	---	---
30	.002	---	.001	.001
31	---	.005	.001	---
32	.007	.007	.006	.003
33	.007	.021	.009	.010
34	.004	.017	.010	.010
35	.002	.004	.002	.003
36	---	---	---	---
37	---	---	---	---
38	.001	.006	---	.001
39	---	---	---	---
40	.025	---	.005	.001
41	---	.001	---	---
42	---	---	.002	.004
43	---	---	---	---
44	---	---	---	---
45	---	.001	.004	.003
46	---	---	---	---
47	.002	---	---	---
48	---	---	---	---
49	---	---	---	---
50	.065	.091	.079	.104
51	.046	.093	.081	.062
52	.009	.004	.007	.009
53	.029	.089	.074	.057
54	---	.004	.003	.001

TABLE 11 (Continued)

Zone	Trip Attractions per Trip Produced			Trip Production per Trip Produced
	Home - Work	Home - Other	Non - Home	Non - Home
55	.022	.004	.005	.005
56	.012	.005	.003	.001
57	.004	.015	.005	.007
58	---	.003	.005	.005
59	.005	.038	.023	.021
60	.018	.059	.027	.018
61	.048	.038	.024	.031
62	.009	.005	.020	.016
63	.018	.055	.033	.029
64	.006	.017	.017	.019
65	.024	.004	.016	.019
66	.050	---	.011	.010
67	.006	---	.003	.003
68	.002	.005	.003	.004
69	---	---	---	---
70	---	---	---	---
71	---	---	---	---
72	---	.003	.011	.006
73	.010	.023	.005	.008
74	.008	.021	.014	.015
75	.002	.022	.028	.018
76	.009	.017	.007	.008
77	---	.020	.041	.034
78	---	.004	---	---
79	---	---	---	---
80	---	---	---	---
81	.001	.002	---	.001
82	---	---	---	---
83	.002	---	---	.002
84	---	.010	---	---
85	---	---	---	---
86	.003	----	---	---
87	---	---	.001	.001
88	---	.002	.003	.002
89	---	---	---	---
90	---	---	---	---
91	---	---	---	---
92	---	.001	.001	---
93	---	---	---	---
94	---	---	.001	.001

Figures 5, 6 and 7 show the trip length frequency distributions, by purpose, for the 14 zones for both the full and reduced samples. There were 402 dwelling units in the reduced samples in the 14 selected zones. The comprehensive O-D survey consisted of 1359 interviews obtained from a 20 per cent sample of dwelling units in the same 14 zones.

The Development of Equations for Estimating Zonal Attractions

The "SCRAP" regression analysis program (13) was used in developing the estimating equations for trip attractions by trip purpose.

There were two sets of equations developed for trip attractions: One set was obtained using the attractions as distributed according to the data from the reduced sample in the 14 selected zones. The second set was obtained using data from the comprehensive O-D survey and utilized data from all zones having 40 or more trips attracted for each of the three purpose groupings.

For the first set of equations, even though trips produced by only 14 zones were used, the attraction ends of the trips were distributed to a great many zones. For example, assume that 10,000 trips of a given purpose were produced by the 14 zones and of these, say, 200 were attracted to Zone 1, 300 to Zone 4, 1,000 to Zone 12, 2,000 to Zone 20, 1,500 to Zone 50, etc. The total of all trips attracted would be 10,000. The trips attracted to each zone were divided by 10,000, the total of trips produced, giving a proportion

FIGURE 5

COMPARISON OF TRIP LENGTH FREQUENCY USING O-D DATA

HOME-WORK TRIPS

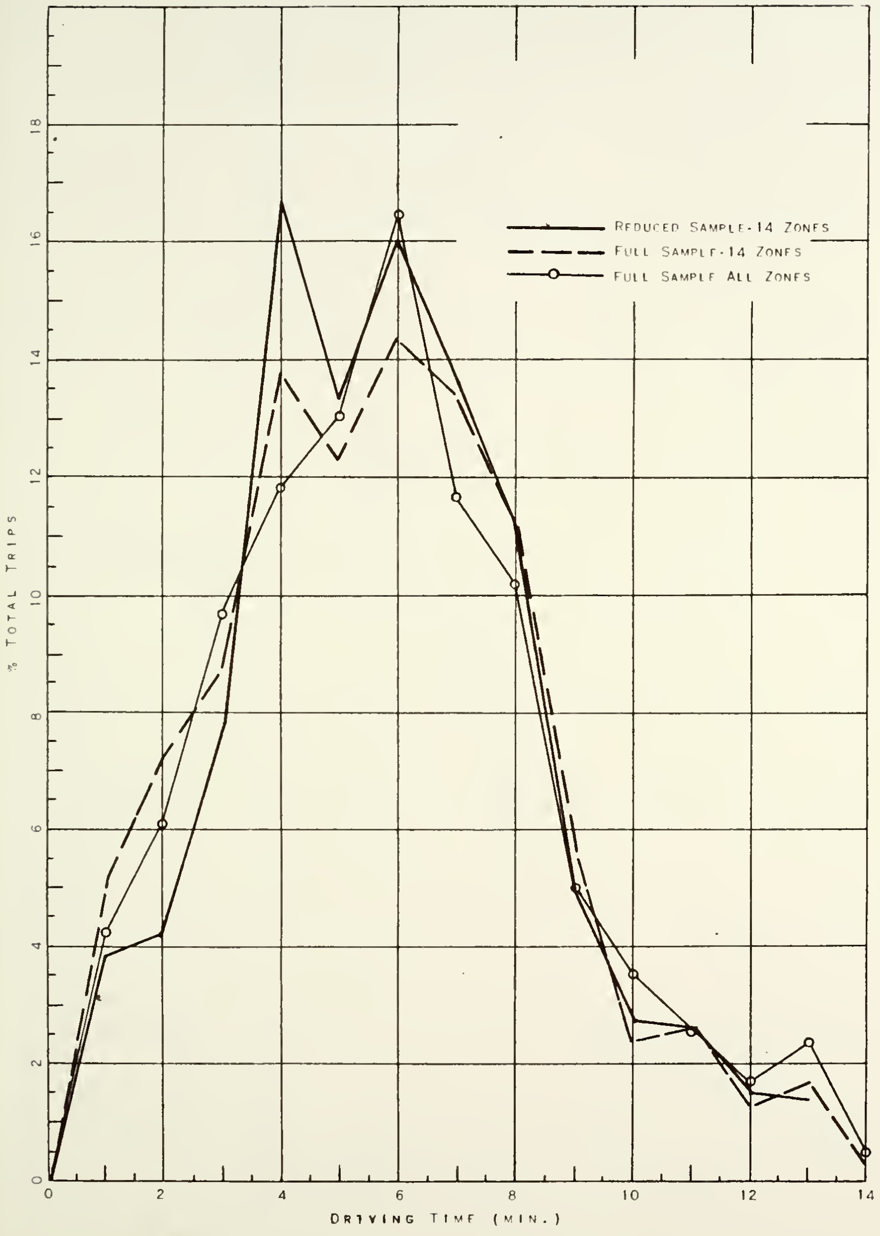


FIGURE 6

COMPARISON OF TRIP LENGTH FREQUENCY USING O-D DATA

HOME-OTHER TRIPS

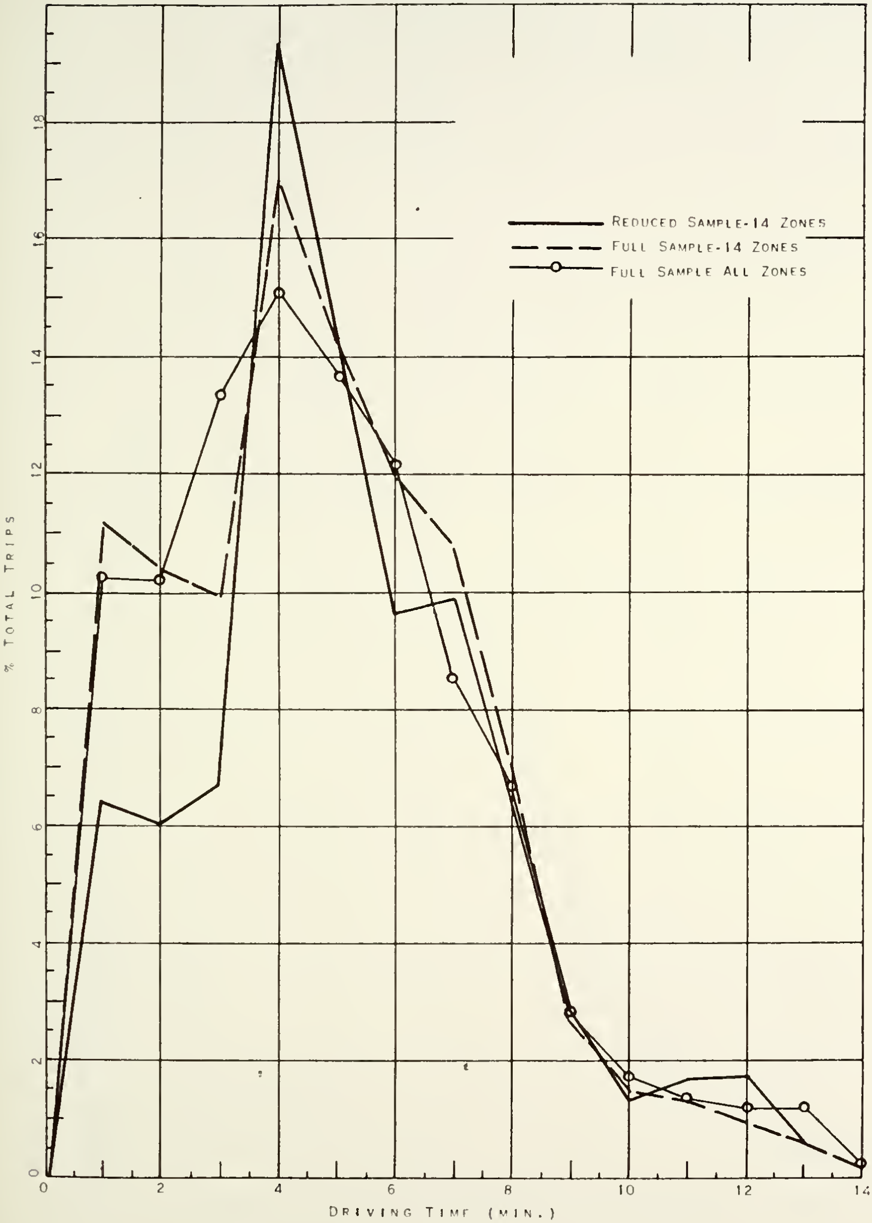
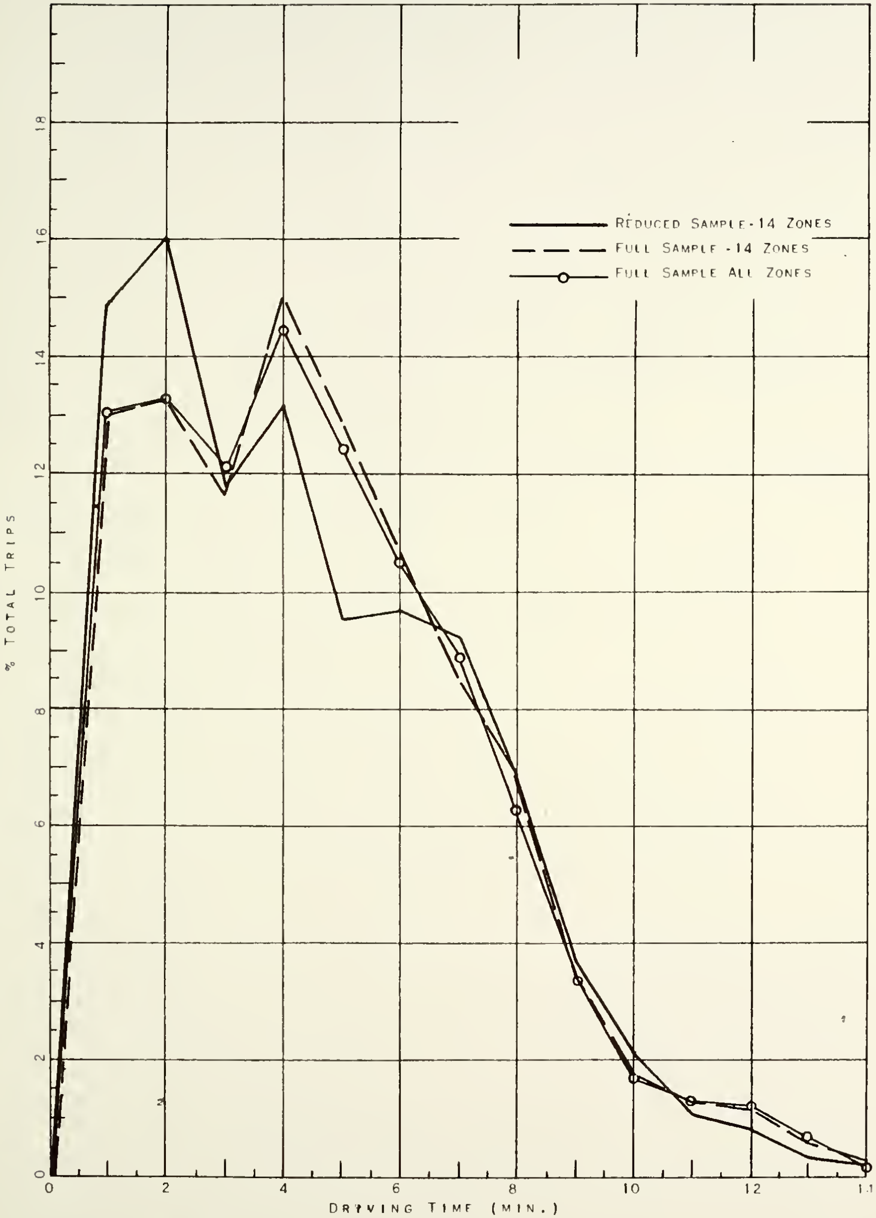


FIGURE 7

COMPARISON OF TRIP LENGTH FREQUENCY USING O-D DATA

NON-HOME TRIPS



of all trips attracted to a given zone. Thus Zone 1 would have 0.02 trips attracted per trip produced, Zone 4 would attract 0.03, Zone 12 would attract 0.10, Zone 20 would attract 0.20 and Zone 50 would attract 0.15 trips per trip produced.

Based upon such zonal characteristics as various types of land use in 1000's of square feet, numbers of jobs of various classifications and total number of persons and dwelling units in the zone, an equation was developed for each trip purpose that estimated the trip attractions in the various zones. The dependent variable was the number of trips attracted per trip produced.

A similar procedure was followed in developing equations based upon the 20 per cent sample obtained in the O-D survey.

The estimating equation for the non-home productions was developed in the same manner as that for trip attractions.

In the case of home-work attractions, it was discovered that the best predictor of trips attracted was the total employment in a zone. Since the "SCRAP" program would not handle a problem with a single independent variable, the equation was developed using a computer program which fitted a polynomial to the data by the method of least squares.

The equation for trip attractions, along with non-home productions, had to be multiplied by the total number of trips produced in the study area in order to give total attractions per zone. Thus, zonal estimates of trip attractions (and non-home productions) were the product of two estimates and in general were less satisfactory than estimates of home-based productions.

In the development of the estimating equations using the "SCRAP" program it was necessary, in each case, to try various relationships among the independent variables. In general, a linear relationship was first tried, followed by more complex equations. The output from each run was examined and those variables were deleted that resulted in a relatively low loss in sum-of-squares when the deletion was made. This rather crude method of selection of variables worked well enough but may also have been partially responsible for the large number of runs on the computer that were necessary to obtain the equations that were judged to be satisfactory.

The Development of Travel Time Factors

The calibration of the gravity model (Equation A, page 8) was carried out using the three trip purposes: home-work, home-other and non-home. The calibration consisted principally of the determination of travel time factors which resulted in a trip length frequency distribution which satisfactorily compared with the trip length frequency distribution of the surveyed population.

Two sets of travel time factors for each trip purpose were determined. One set was determined using zonal productions and attractions from the comprehensive O-D survey while zonal productions and attractions obtained from the reduced sample size in the 14 selected zones were used for the second set of travel time factors.

The gravity model formula as used requires input parameters of zonal trip productions, attractions, travel time factors and zone-

to-zone adjustment factors (see page 8). The zone-to-zone adjustment factors were used as unity throughout this study because of no apparent effect on travel patterns of defined zonal characteristics.

The travel times used for determination of the corresponding travel time factors for use in the gravity model were made up of the terminal time on each end of the trip plus the zone to zone driving time. The zone to zone minimum driving time was obtained from the "time trees" which were developed from travel-time study data. The driving time for intrazonal trips (those trips with both ends in a given zone) was not available from the time trees and was estimated at one minute for each zone. The intrazonal time was chosen after inspection of interzonal times for all adjacent zones. The interzonal times of adjacent zones were, in all cases, slightly less than two minutes. The maximum intrazonal time was also about two minutes and a reasonable average time was believed to be one minute. Reference (1) discusses other methods of determining intrazonal times.

The terminal time of one end of a trip may be made up of the time spent in cruising for a parking space, the time spent waiting before a vehicle can be parked and the time spent walking from the parking place to the actual destination. The terminal time of the other end of the trip may consist of the time spent walking from home to garage or parking lot and the time from garage or parking lot onto the street system. The terminal times for the zones in Hutchinson were estimated, initially, after consultation with personnel who were familiar with Hutchinson. The CBD, Zones 12, 13 and 50 (Figure 1), were each given terminal times of three

minutes and each of the zones adjacent to the CBD was given a terminal time of two and one-half minutes with each of the remaining zones being given a terminal time of one and one-half minutes. It was found that some changes in these terminal times resulted in better trip end balance for some zones and some trip purposes. Table 12 shows the final sets of terminal times used in the study.

The interzonal travel time between any two zones was made up of the terminal time of the production zone plus the driving time between the zones plus the terminal time of the attraction zone.

Intrazonal travel time for a given zone was made up of twice the zonal terminal time plus the intrazonal driving time for that zone.

A set of travel time factors using the comprehensive O-D zonal productions and attractions was developed as follows: An initial set of travel time factors was assumed and the trip interchanges between all zones were computed. The trip length frequency distribution of the trip interchanges was determined by finding the number and the percentage of trips falling in each one minute increment of driving time. The estimated trip length frequency was then compared with the actual trip length frequency distribution obtained from the O-D data. The comparison was made in three ways: First, both distributions expressed as per cent trips for each one minute driving time should, when plotted, be relatively close to one another; second, the average trip length, in minutes, for both sets of data should be within ±5 per cent of each other; and, third, the person hours of travel for both sets of data should be within ±5 per cent

TABLE 12

FINAL TERMINAL TIMES BY ZONE AND TRIP PURPOSE

Terminal Time (Min.)	Trip Purpose		
	Home-Work	Home - Other	Non - Home
3.0	* 12, 13, 50	(None)	12, 13, 50
2.5	** 14,15,16,17,18,51, 52,53	(None)	14,15,16,17,18,51, 52,53
2.0	*** 19,58,59,60,61,63	12,13,14,15,16,17, 18,19,50,51,62,53, 58,59,60,61,63	19,58,59,60,61,63
1.5	**** All Others	All Others	All Others

* CBD zones

** Adjacent zones to CBD

*** Other highly developed zones

**** Relatively undeveloped zones

of each other (1). The average trip length was determined by multiplying the number of trips of each incremental trip length by the length of trip (driving time) in minutes and dividing this product by the total number of trips.

The vehicle hours of travel were obtained by multiplying the number of trips of each incremental trip length by the length of trip in minutes and dividing the product by 60.

Computer programs* were written to determine the trip length distributions as well as the average trip length and vehicle hours of travel.

If the comparisons were not within the limits cited above, then an adjustment was made in the initially assumed set of travel time factors for each trip purpose. The travel time factors were adjusted manually by a procedure which follows from the question: "What must be done to the travel time factor at each travel time increment to bring the gravity model estimated percentage of trips, in each travel time increment, into closer agreement with the surveyed trips at each increment?" The actual adjustment was made for each travel time increment by multiplying the initial travel time factor for each increment by the ratio of the percentage of surveyed trips to the percentage of estimated trips for the respective time increments. The adjusted travel time factors (for each one minute of travel time) were then plotted against the respective travel time increments on log-log graph paper in most cases and straight-line graph paper in others. The second set of travel time factors was

* See Appendix B

then determined from a hand-fitted line of best fit to the adjusted factors. The gravity model was then run using the second set of travel time factors and the comparisons of trip length frequency, etc. were repeated. This process was continued until satisfactory agreement among the comparisons was reached.

In the case of home-work trips 12 sets of adjustments were required before acceptable agreement was reached. Better estimates of initial travel time factors would have resulted in fewer iterations being required. This was graphically illustrated in the case of home-other trips when the Iowa travel time factors (9, 16) shown in Table 13 were used for the initially estimated factors and required only four iterations. In addition, much time was spent in adjusting to the trip length frequency curve. The researcher is of the opinion that if two-minute increments of travel time had been used satisfactory results would have been obtained much more quickly.

The second set of travel time factors was developed in a manner similar to that explained above with the exception that productions and attractions obtained from data from the 14 zones with the reduced sample size were used. The trip length frequency, average trip length and vehicle hours of travel, against which comparisons were made, were those resulting from the O-D data obtained from the reduced sample size in the 14 zones. The Iowa travel time factors (9, 16) were used as the first estimate of the factors used for each trip purpose. From three to seven iterations were necessary to arrive at acceptable factors. The computer time was much reduced because of the great reduction in number of trips to be distributed.

TABLE 13

CEDAR RAPIDS (IOWA) TRAVEL TIME FACTORS*

Travel Time (Min.)	Travel Time Factors by Purpose			Travel Time (Min.)	Travel Time Factors by Purpose		
	Work	Non Home Based	Other Home Based		Work	Non Home Based	Other Home Based
1	2.00	3.00	5.00	28	0.33	0.07	0.10
2	2.00	2.25	3.66	29	0.31	0.06	0.09
3	2.00	1.80	2.20	30	0.29	0.05	0.08
4	1.50	1.40	1.45	31	0.27	0.04	0.06
5	1.25	1.15	1.20	32	0.25	0.03	0.04
6	1.10	1.00	1.00	33	0.23	0.02	0.03
7	1.00	0.90	0.90	34	0.21	0.01	0.02
8	0.93	0.80	0.80	35	0.19	0.01	0.01
9	0.87	0.70	0.70	36	0.17		
10	0.84	0.62	0.62	37	0.15		
11	0.80	0.56	0.56	38	0.14		
12	0.76	0.49	0.50	39	0.13		
13	0.72	0.43	0.45	40	0.12		
14	0.68	0.38	0.41	41	0.11		
15	0.64	0.34	0.38	42	0.10		
16	0.61	0.30	0.35	43	0.09		
17	0.58	0.27	0.32	44	0.08		
18	0.55	0.24	0.30	45	0.07		
19	0.52	0.22	0.27	46	0.06		
20	0.49	0.20	0.25	47	0.05		
21	0.47	0.18	0.23	48	0.04		
22	0.45	0.16	0.21	49	0.04		
23	0.43	0.14	0.19	50	0.04		
24	0.41	0.12	0.17	51	0.03		
25	0.39	0.10	0.15	52	0.03		
26	0.37	0.09	0.13	53	0.02		
27	0.35	0.08	0.11				

*Source: Ref. (9, 16)

Figures 8, 9, and 10 show the comparison of trip length distributions as obtained for the 14 zone, reduced sample O-D data versus the model distribution using the second set of travel time factors.

Table 14 shows the best set of travel time factors developed in each case.

Figures 11, 12 and 13 show a graphical comparison of travel time factors developed.

The trip length frequency data were developed on the basis of driving time rather than travel time. An examination of the computational procedures indicates that with little difficulty the distribution could have been made on the basis of travel time, provided that terminal times were introduced as input data.

FIGURE 8

COMPARISON OF TRIP LENGTH FREQUENCY USING O-D AND MODEL DATA

HOME-WORK TRIPS

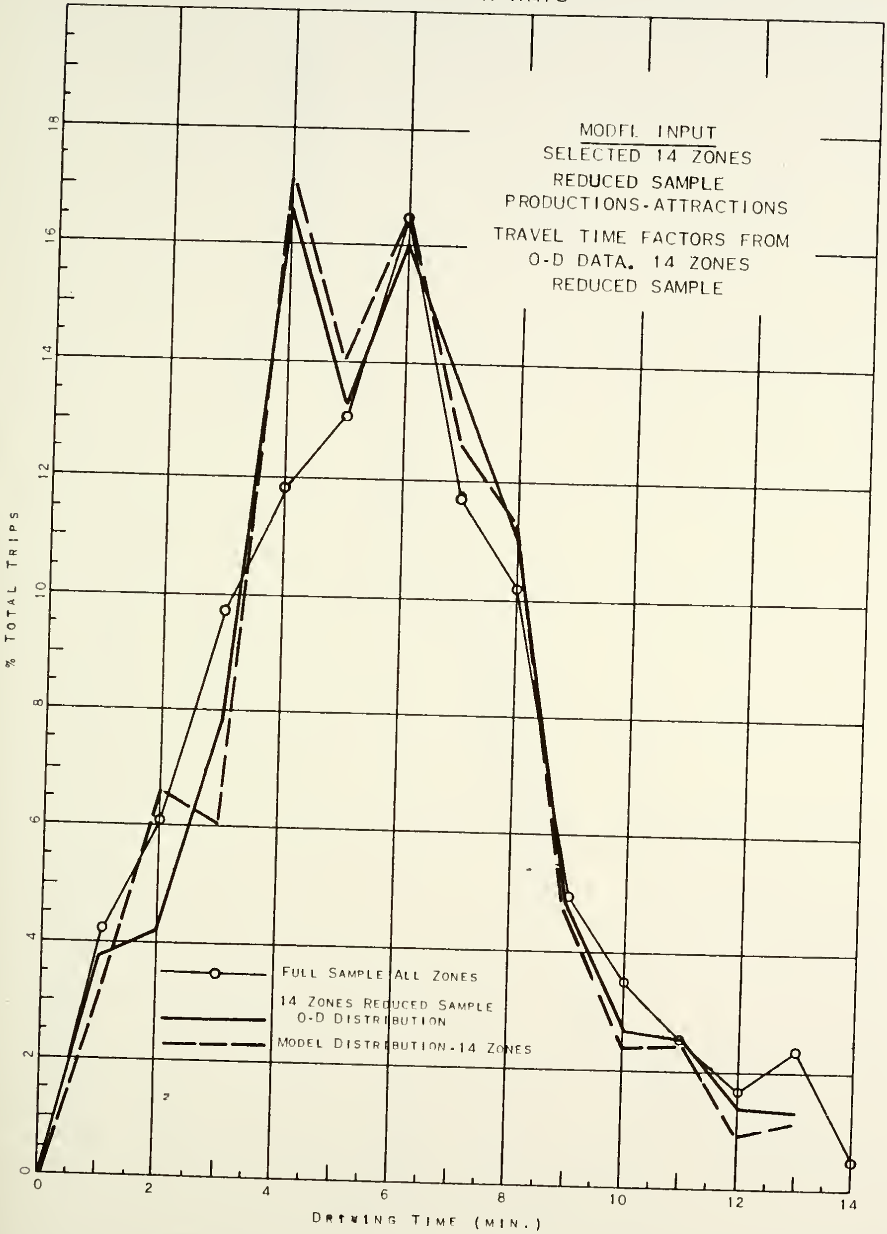


FIGURE 9

COMPARISON OF TRIP LENGTH FREQUENCY USING O-D AND MODEL DATA

HOME-OTHER TRIPS

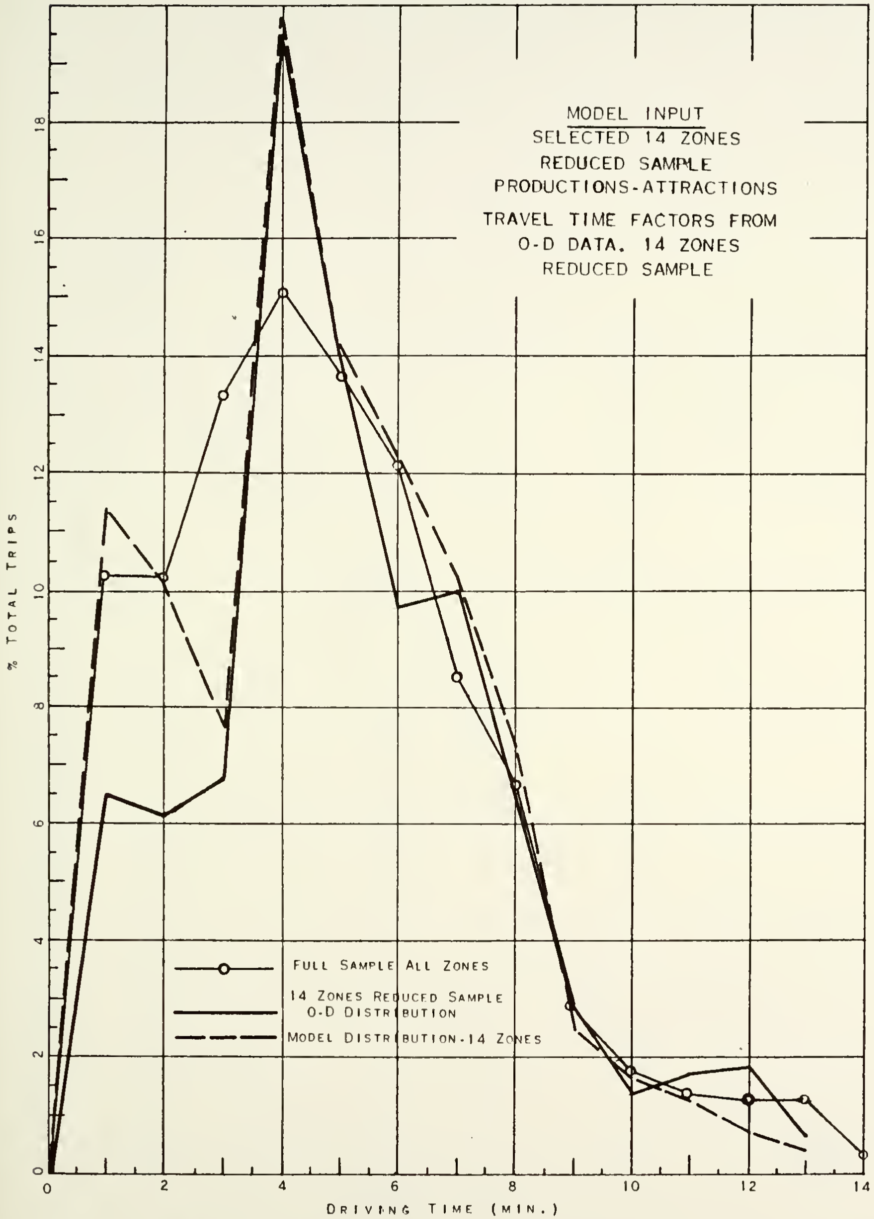


FIGURE 10

COMPARISON OF TRIP LENGTH FREQUENCY USING O-D AND MODEL DATA

NON-HOME TRIPS

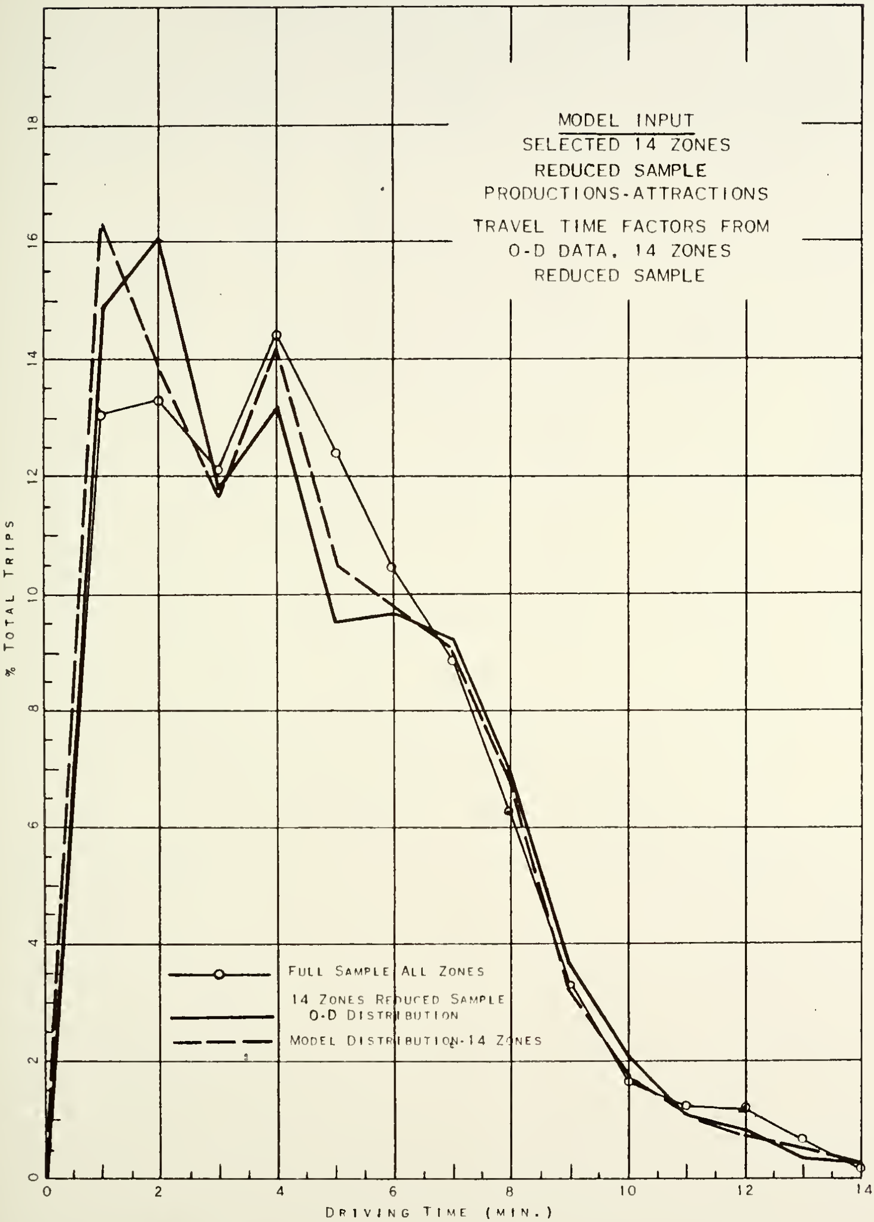


TABLE 14

TRAVEL TIME FACTORS BY TRIP PURPOSE

Travel Time (Min.)	Travel Time Factors					
	Home - Work		Home - Other		Non - Home	
	F.S.*	R.S.**	F.S.*	R.S.**	F.S.*	R.S.**
4	2.78	2.12	1.74	2.70	1.40	3.00
5	2.40	1.70	1.22	1.84	1.15	2.25
6	2.20	1.41	.94	1.23	1.00	1.80
7	1.97	1.20	.78	.91	.90	1.40
8	1.78	1.06	.65	.68	.80	1.15
9	1.58	.93	.56	.51	.70	1.00
10	1.43	.84	.49	.41	.62	.90
11	1.32	.76	.43	.34	.56	.80
12	1.20	.70	.39	.28	.49	.70
13	1.12	.65	.35	.23	.43	.62
14	1.04	.60	.32	.19	.38	.56
15	.96	.56	.30	.17	.34	.49
16	.90	.53	.28	.14	.30	.43
17	.85	.49	.25	.12	.27	.38
18	.80	.46	.23	.11	.24	.34
19	.76	.44	.21	.10	.22	.30
20	.72	.43	.20	.09	.20	.27

* F.S. - Model Input: Full Sample O-D Productions-Attractions, All zones

** R.S. - Model Input: Reduced Sample O-D Productions-Attractions, 14 zones

Note: No travel time of less than four (4) minutes was possible for any trip.

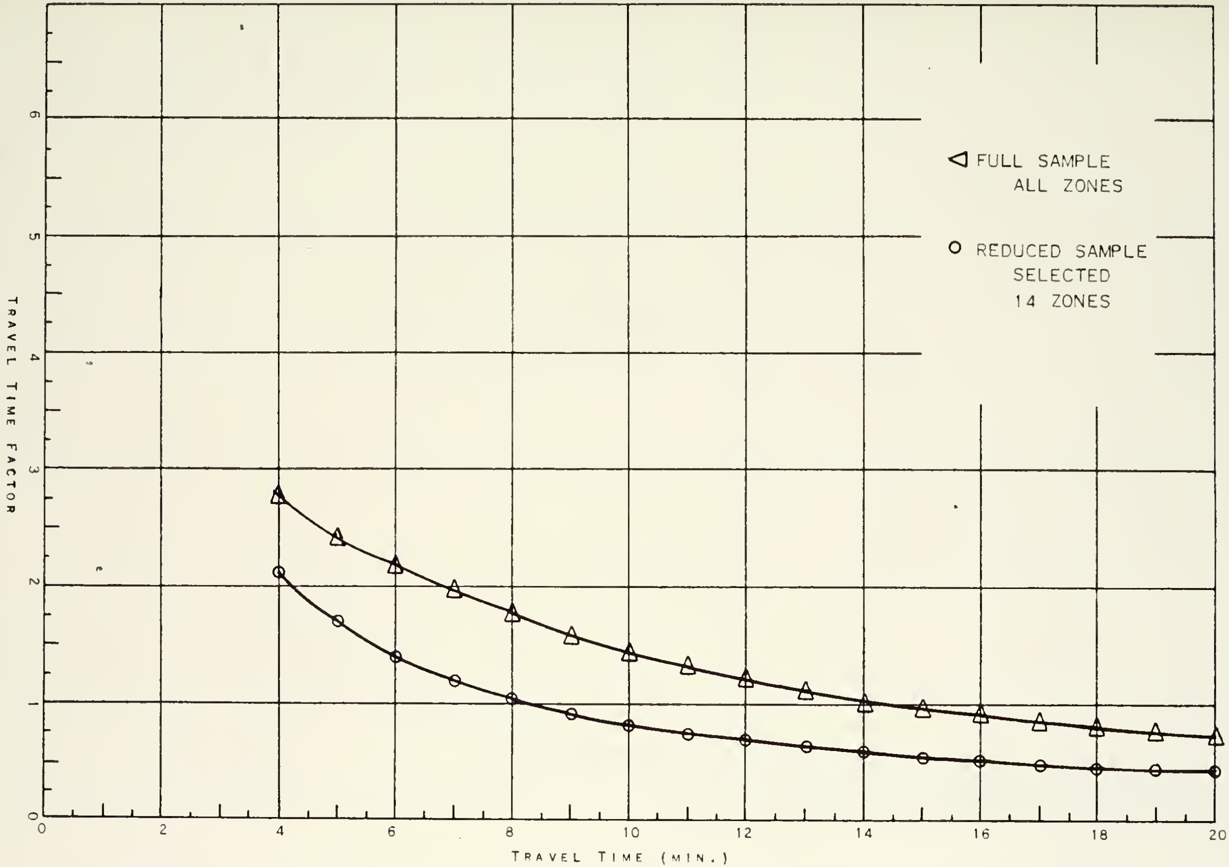


FIGURE 11
COMPARISON OF TRAVEL TIME FACTORS - FULL SAMPLE VS. REDUCED SAMPLE O-D DATA
HOME-WORK TRIPS

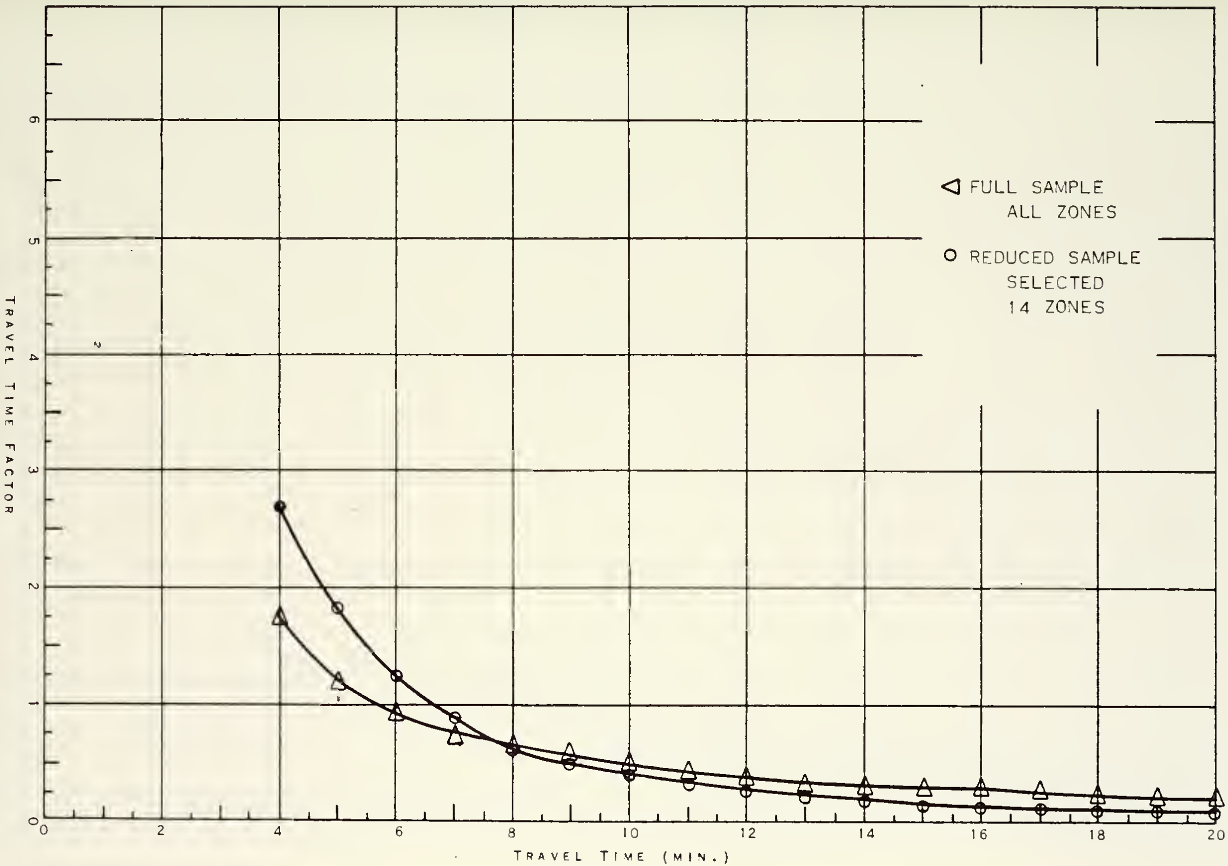


FIGURE 12
COMPARISON OF TRAVEL TIME FACTORS - FULL SAMPLE VS. REDUCED SAMPLE O-D DATA
HOME-OTHER TRIPS

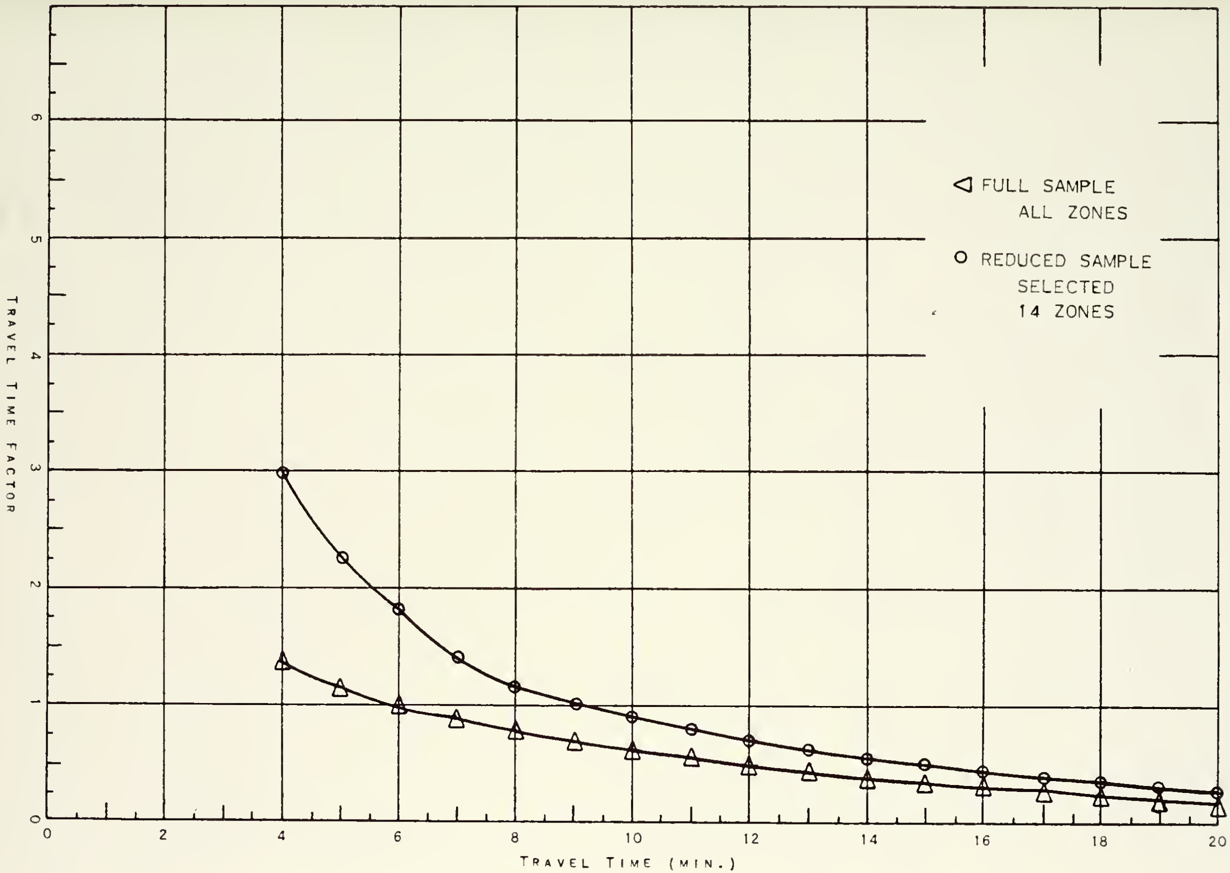


FIGURE 13
COMPARISON OF TRAVEL TIME FACTORS - FULL SAMPLE VS. REDUCED SAMPLE O-D DATA
NON-HOME TRIPS

ANALYSIS OF RESULTS

Estimates of Trip Production and Attraction

The estimating equations for trip productions and attractions as developed using the regression analysis technique are shown in Tables 15 and 16. The coefficients of correlation, as obtained from the "SCRAP" regression analysis program are shown in Table 17.

The squared correlation coefficient or coefficient of determination, R^2, is a measure of the amount of variation about the mean that the estimating equation explains. It was found, however, that although many of the R^2 values were quite high, that this coefficient did not necessarily indicate the predictive power of the various equations. For the same data, however, higher values of R^2 did indicate better predictive power of the form of equation being used.

A more meaningful statistical test of the estimating power of the equations was felt to be the calculation of root-mean-square (RMS) errors. The RMS error for each equation was computed by summing the squares of the differences between the estimated and surveyed values of production or attraction and dividing the total squared differences by the number of zoned productions or attractions and finding the square root of the quotient.

TABLE 15*

ESTIMATING EQUATIONS FOR TRIP PRODUCTION FROM MULTIPLE REGRESSION ANALYSES

Equation No. 1 - OSP 22030 - Home-Work - Full Sample

$$Y = -5.78775 + 10.25491(\text{Cars/DU}) + 1.52715(\text{Pers./DU}) - 0.70627(\text{CBD Dist.})$$
$$- 2.66103(\text{Cars/DU})(\text{Pers./DU}) + 0.30996(\text{Pers./DU})(\text{CBD Dist.}) - 0.039634(\text{CBD Dist.})^2$$

Y = Trips/Dwelling Unit

Equation No. 2 - RSP 14030 - Home-Work - Reduced Sample

$$Y = -0.54297 - 0.96297(\text{Cars/DU}) + 0.79424(\text{Pers./DU}) + 0.13594(\text{CBD Dist.})$$
$$+ 0.31954(\text{Cars/DU})(\text{Pers./DU}) - 0.10496)(\text{Pers./DU})(\text{CBD Dist.}) + 0.018626(\text{CBD Dist.})^2$$

Y = Trips/Dwelling Unit

Equation No. 3 - OSP 22039 - Home-Other - Full Sample

$$Y = -5.92767 + 11.60937(\text{Cars/DU}) + 1.39224(\text{Pers./DU}) - 1.20225(\text{CBD Dist.})$$
$$- 2.26609(\text{Cars/DU})(\text{Pers./DU}) + 0.29830(\text{Pers./DU})(\text{CBD Dist.}) + 0.007200(\text{CBD Dist.})^2$$

Y = Trips/Dwelling Unit

*See note at end of Table 16.

TABLE 15 (Cont.)

Equation No. 4 - RSP 14039 - Home-Other - Reduced Sample

$$Y = 4.56907 - 6.09284(\text{Cars/DU}) - 1.69056(\text{Pers./DU}) + 0.58893(\text{CBD Dist.})$$
$$+ 2.98149(\text{Cars/DU})(\text{Pers./DU}) - 0.29073(\text{Pers./DU})(\text{CBD Dist.}) + 0.042162(\text{CBD Dist.})^2$$

Y = Trips/Dwelling Unit

Equation No. 5 - NHP 04514 - Non-Home - Full Sample

$$Y = -2.398094 - 0.0051391(LU_1) - 0.017017(LU_5) + 0.054498(LU_6) + 0.058424(\text{Jobs})$$
$$+ 0.048989(\text{Pers./Zone}) - 0.084438(\text{Tot. DU/Zone}) - 0.017802(\text{Cars/Zone})$$
$$+ 0.0000005793(LU_1)^2 + 0.000003317(LU_5)^2 + 0.00052392(LU_6)^2 - 0.000023462(\text{Jobs})^2$$
$$- 0.000023616(\text{Pers./Zone})^2 + 0.000089245(\text{Tot. DU/Zone})^2 + 0.000060598(\text{Cars/Zone})^2$$

Y = Trips/Zone/1000 trips produced in 14 selected zones

Equation No. 6 - NRP 04514 - Non-Home - Reduced Sample

$$Y = -6.22386 - 0.0046915(LU_1) + 0.043900(LU_5) + 0.045839(LU_6) + 0.070971(\text{Jobs})$$
$$+ 0.058497(\text{Pers./Zone}) - 0.15106(\text{Tot. DU/Zone}) + 0.038259(\text{Cars/Zone})$$
$$+ 0.0000005283(LU_1)^2 - 0.00020223(LU_5)^2 + 0.00064132(LU_6)^2 - 0.00002833(\text{Jobs})^2$$
$$- 0.00002883(\text{Pers./Zone})^2 + 0.00013757(\text{Tot. DU/Zone})^2 + 0.00002562(\text{Cars/Zone})^2$$

Y = Trips/Zone/1000 trips produced in 14 selected zones

TABLE 16*

ESTIMATING EQUATIONS FOR TRIP ATTRACTION FROM MULTIPLE REGRESSION ANALYSES

Equation No. 7 - Work Trip Attr. - Home-Work - Full Sample (Adj. Jobs)

$Y = 1.109 + 0.0624\,(\text{Jobs})$

Y = Trips/Zone/1000 trips produced in 14 selected zones

Equation No. 8 - RS 460 - Home-Work - Reduced Sample (Zone 12 Omitted)

$Y = 1.092802 + 0.058113(\text{Jobs})$

Y = Trips/Zone/1000 trips produced in 14 selected zones

Equation No. 9 - MRA 51409 - Home-Other - Full Sample

$$
\begin{aligned}
Y = {} & -0.62306 - 0.048951(LU_6) + 0.005561(LU_9) - 0.0052420(\text{Pers./Zone}) + 0.035644(\text{Tot.DU/Zone}) \\
& - 0.050611(\text{Who.-Ret. Jobs}) + 0.06504(\text{Pers. Serv. Jobs}) + 0.064090(\text{Prof. Jobs}) \\
& - 0.012982(\text{Grouped Jobs}) + 0.32256(LU_{220}) + 1.95827(LU_{240}) + 1.63904(LU_{250}) + 0.39525(LU_{280}) \\
& + 0.00017289(LU_6)^2 - 0.00000037908(LU_9)^2 - 0.0000001466(\text{Pers./Zone})^2 \\
& + 0.000018689(\text{Tot. DU/Zone})^2 - 0.0000094125(\text{Who.-Ret. Jobs})^2 - 0.00061319(\text{Prof. Jobs})^2 \\
& + 0.0001369(\text{Grouped Jobs})^2 - 0.0032360(LU_{220})^2 - 0.054781(LU_{240})^2 - 0.0055373(LU_{280})^2
\end{aligned}
$$

Y = Trips/Zone/1000 trips produced in 14 selected zones

* See note at end of table.

TABLE 16 (Cont.)

Equation No. 10 - RSA 51309 - Home-Other - Reduced Sample

$$Y = -\,0.021097 - 0.080372(LU_6) + 0.0045021(LU_9) + 0.0078854(\text{Pers./Zone})$$
$$-\,0.013214(\text{Tot. DU/Zone}) - 0.049754(\text{Who.-Ret. Jobs}) + 0.26185(\text{Pers. Serv. Jobs})$$
$$-\,0.018923(\text{Prof. Jobs}) - 0.0041486(\text{Grouped Jobs}) + 0.35568(LU_{220}) + 0.88353(LU_{240})$$
$$+\,2.63884(LU_{250}) + 0.35530(LU_{280}) + 0.00017385(LU_6)^2 - 0.0000003212(LU_9)^2$$
$$-\,0.000003921(\text{Pers./Zone})^2 + 0.000059441(\text{Tot. DU/Zone})^2 - 0.000024614(\text{Who.-Ret. Jobs})^2$$
$$-\,0.00003059(\text{Prof. Jobs})^2 + 0.000078437(\text{Grouped Jobs})^2 - 0.0031158(LU_{220})^2$$
$$-\,0.032500(LU_{240})^2 - 0.0043047(LU_{280})^2$$

Y = Trips/Zone/1000 trips produced in 14 selected zones

Equation No. 11 - NHA 04714 - Non-Home - Full Sample

$$Y = -\,0.722068 - 0.004496(LU_1) - 0.055532(LU_5) + 0.052999(LU_6) + 0.045612(\text{Jobs})$$
$$+\,0.02664(\text{Pers./Zone}) - 0.0314071(\text{Tot. DU/Zone}) - 0.009572(\text{Cars/Zone}) + 0.0000005513(LU_1)^2$$
$$+\,0.00012975(LU_5)^2 + 0.00045254(LU_6)^2 - 0.000019178(\text{Jobs})^2 - 0.000016506(\text{Pers./Zone})^2$$
$$+\,0.000061364(\text{Tot. DU/Zone})^2 + 0.000044775(\text{Cars/Zone})^2$$

Y = Trips/Zone/1000 trips produced in 14 selected zones

TABLE 16 (Cont.)

Equation No. 12 - NRA 04714 - Non-Home - Reduced Sample

$$Y = -3.03559 - 0.0073974(LU1) - 0.024895(LU_5) - 0.0027639(LU_6) + 0.056735(Jobs)$$

$$+ 0.062327(Pers./Zone) - 0.11725(Tot.\ DU/Zone) - 0.014188(Cars/Zone)$$

$$+ 0.0000014912\,(LU_1)^2 + 0.000048958\,(LU_5)^2 + 0.00063131(LU_6)^2 - 0.00002446(Jobs)^2$$

$$- 0.00002917(Pers./Zone)^2 + 0.00014079(Tot.\ DU/Zone)^2 + 0.000049897(Cars/Zone)^2$$

Y = Trips/Zone/1000 trips produced in 14 selected zones

Equation No. 13 - OSP 14034 - Non-Home - Full Sample

$$Y = 3.34575 - 6.39670(Cars/DU) - 0.52092(Pers./DU)$$

$$+ 0.000120(CBD\ Dist.) + 2.52203(Cars/DU)(Pers./DU)$$

$$- 0.35194(Pers./DU)(CBD\ Dist.) + 0.13654(CBD\ Dist.)^2$$

Y = Trips/Dwelling Unit

Equation No. 14 - RSP 14034 - Non-Home - Reduced Sample

$$Y = 3.75602 - 6.31798(Cars/DU) - 1.19446(Pers./DU) + 0.46274(CBD\ Dist.)$$

$$+ 2.76797(Cars/DU)(Pers./DU) - 0.45012(Pers./DU)(CBD\ Dist.)$$

$$+ 0.13799(CBD\ Dist.)^2$$

Y = Trips/Dwelling Unit

TABLE 16 (Cont.)

Note: Equations 13 and 14 were used only for the estimation of <u>numbers</u> of non-home productions or attractions.

1. LU_x indicates 1000's of square feet of land use

   x, if single digit, indicates <u>major group</u> land use

   x, if 3 digit, indicates land use categories <u>within</u> major group land uses

   (See appendix A for land use codes)

2. In equations 1, 2, 3, 4, 13, 14:

   DU = dwelling units which responded to the O-D interview

   Pers. = persons

   CBD Dist. = distance from the zone centroid in question to the centroid of zone 12, in minutes.

3. In equations 5, 6, 7, 8, 9, 10, 11, 12:

   Tot. DU/Zone = Total number of dwelling units per zone

   Grouped Jobs = Total jobs in wholesale, retail, finance, personal services, amusement, recreation, professional government, and self-employed.

   Jobs = Total of all jobs

   Who.-Ret. Jobs - Total jobs in wholesale, retail, finance and insurance

   Pers. Serv. Jobs = Total jobs in personal service

   Prof. Jobs = Total jobs in professional area

TABLE 17

COEFFICIENTS OF CORRELATION AND DETERMINATION FROM REGRESSION ANALYSIS

Equation/1	Coefficient of Correlation R	Coefficient of Determination R^2
1	.936	.876
2	.952	.907
3	.918	.843
4	.912	.831
5	.995	.990
6	.991	.982
7	/2	/2
8	/2	/2
9	.994	.989
10	.992	.984
11	.995	.990
12	.986	.972
13	.968	.937
14	.961	.923

/1 See Table 15 or 16 for the form of the equation

/2 Not determined, equation developed in "polynomial best fit" program. See Table 18 for RMS error comparisons.

The following equation was used for computing the RMS error:

$$\text{RMS error} = \sqrt{\frac{(Y - Y_{est})^2}{N}}$$

Where

Y = Surveyed value

Y_{est} = Value estimated from regression equation

N = Number of values.

The RMS error indicates the limits within which about two-thirds of the deviations between the observed and the estimated values will fall. The RMS errors, shown in Table 18, for the developed estimating equations were smallest, in each case, when the regression equation was based upon data obtained from the comprehensive O-D survey. The recorded RMS error, in most cases, appears to be reasonable when one considers that this is equivalent to stating that two-thirds of the time the estimated zonal productions or attractions can be expected to be within one RMS error of the actual value. The estimating power of equations 6, 8, 10 and 12 were much improved when O-D survey productions were used to expand to zonal values. A plot of the estimated values versus O-D values of zonal productions or attractions provided an excellent graphical portrayal of the "goodness of fit" of the estimating equations. Figures 14 through 25 show the comparison of O-D trips per zone by purpose, to the estimated zonal trips as obtained from equations 1 through 12. If the estimated value was equal to the O-D value, the plotted point fell on the "45° line". The plot of the "O-D value ± RMS error" versus the O-D value would indicate a band within which one would expect the estimated values to fall about 2/3 of the time.

TABLE 18

RMS ERRORS OF ESTIMATING EQUATIONS

Equation/1	Average Trips per Zone	RMS Error	% RMS Error /4
1	302	65	21
2	297	118	40
3	545	137	25
4	545	171	31
5	306	71	23
6 /2	306	218	71
6 /3	307	146	48
7	219	39	18
8 /2	219	88	40
9	452	208	51
10 /2	411	208	51
11	297	65	22
12 /2	306	220	72
12 /3	306	162	53

/1 See Table 15 or 16 for the form of the equation

/2 Using estimated total non-home productions to expand to zonal totals

/3 Using O-D total non-home productions to expand to zonal totals

/4 % RMS error = 100 (RMS error)/average trips per zone

FIGURE 14

COMPARISON OF HOME-WORK TRIPS PRODUCED (EQUATION NO. 1)

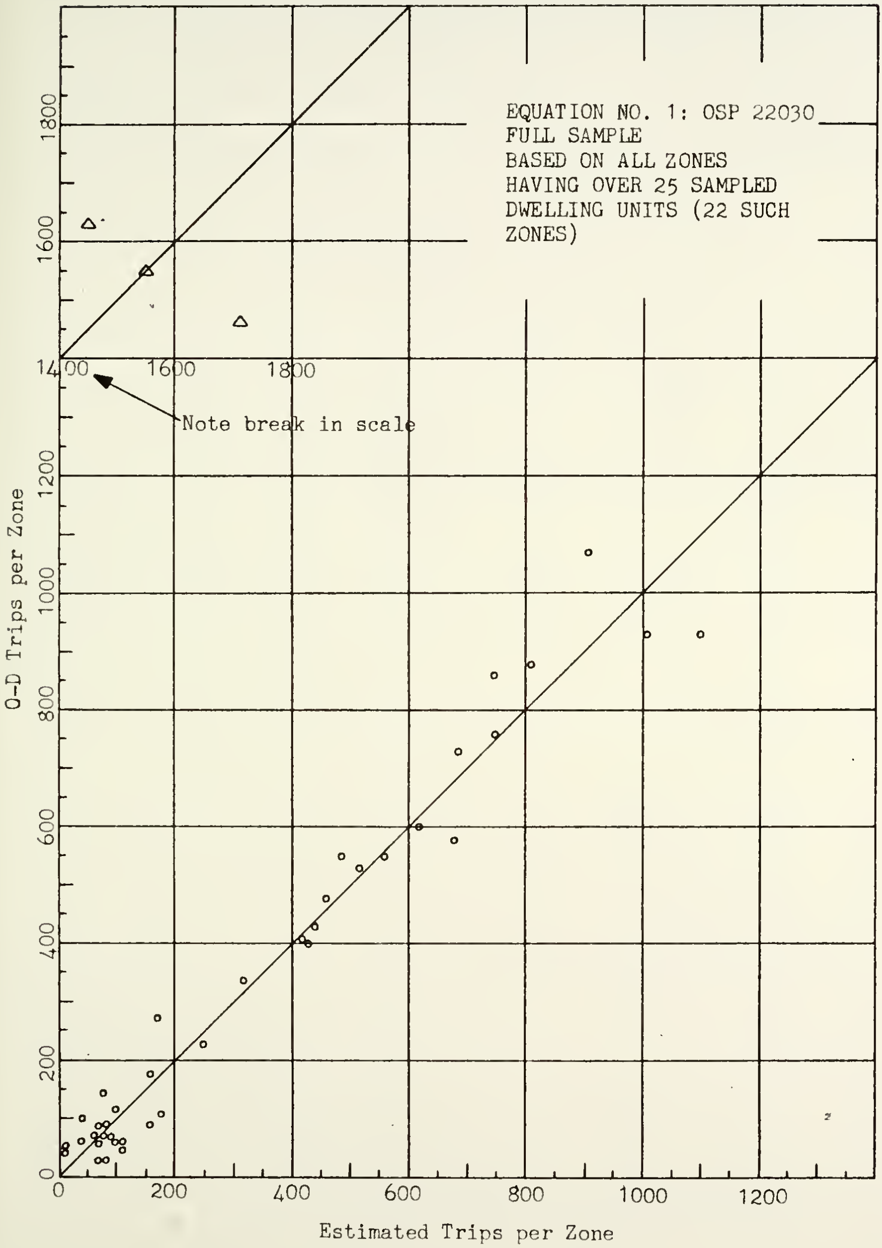


FIGURE 15

COMPARISON OF HOME-WORK TRIPS PRODUCED (EQUATION NO. 2)

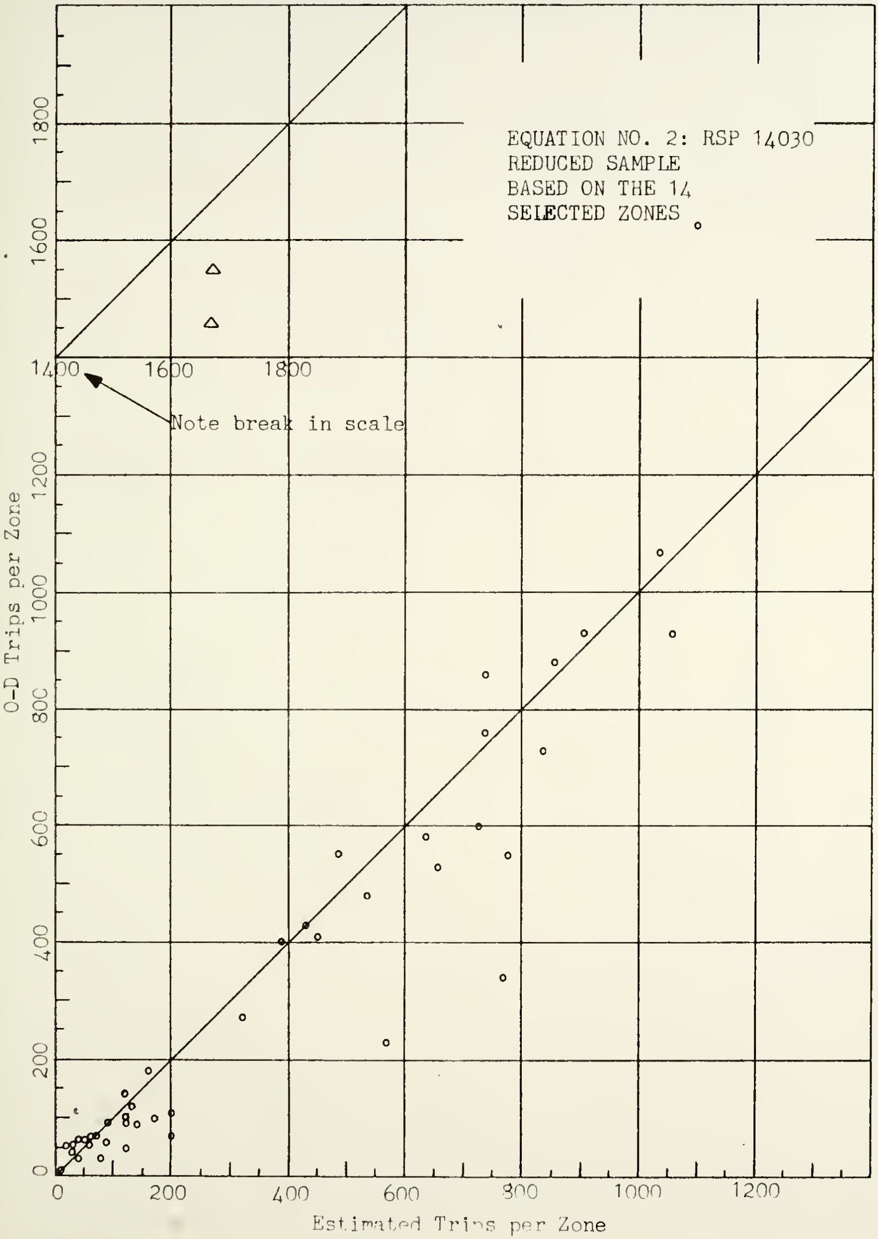


FIGURE 16

COMPARISON OF HOME-OTHER TRIPS PRODUCED (EQUATION NO. 3)

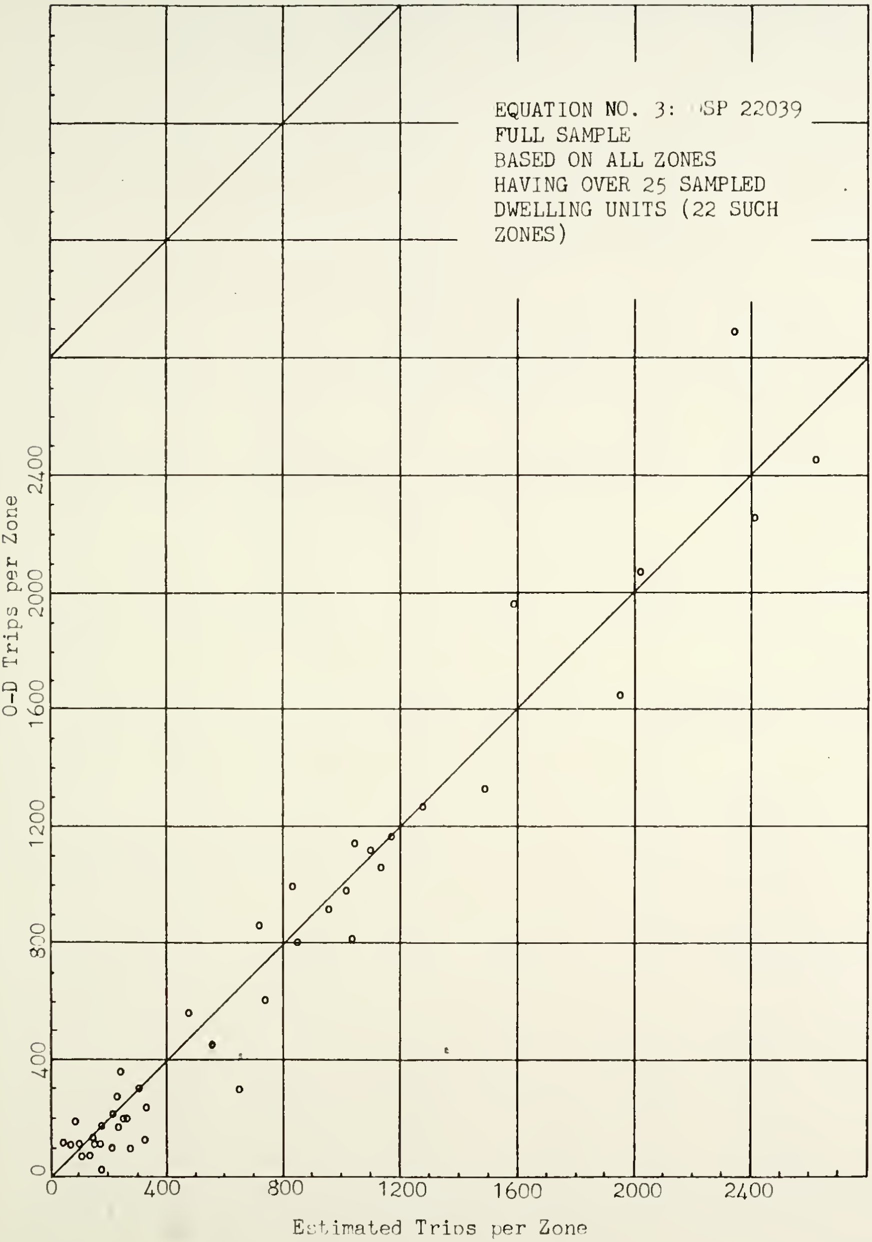


FIGURE 17

COMPARISON OF HOME-OTHER TRIPS PRODUCED (EQUATION NO. 4)

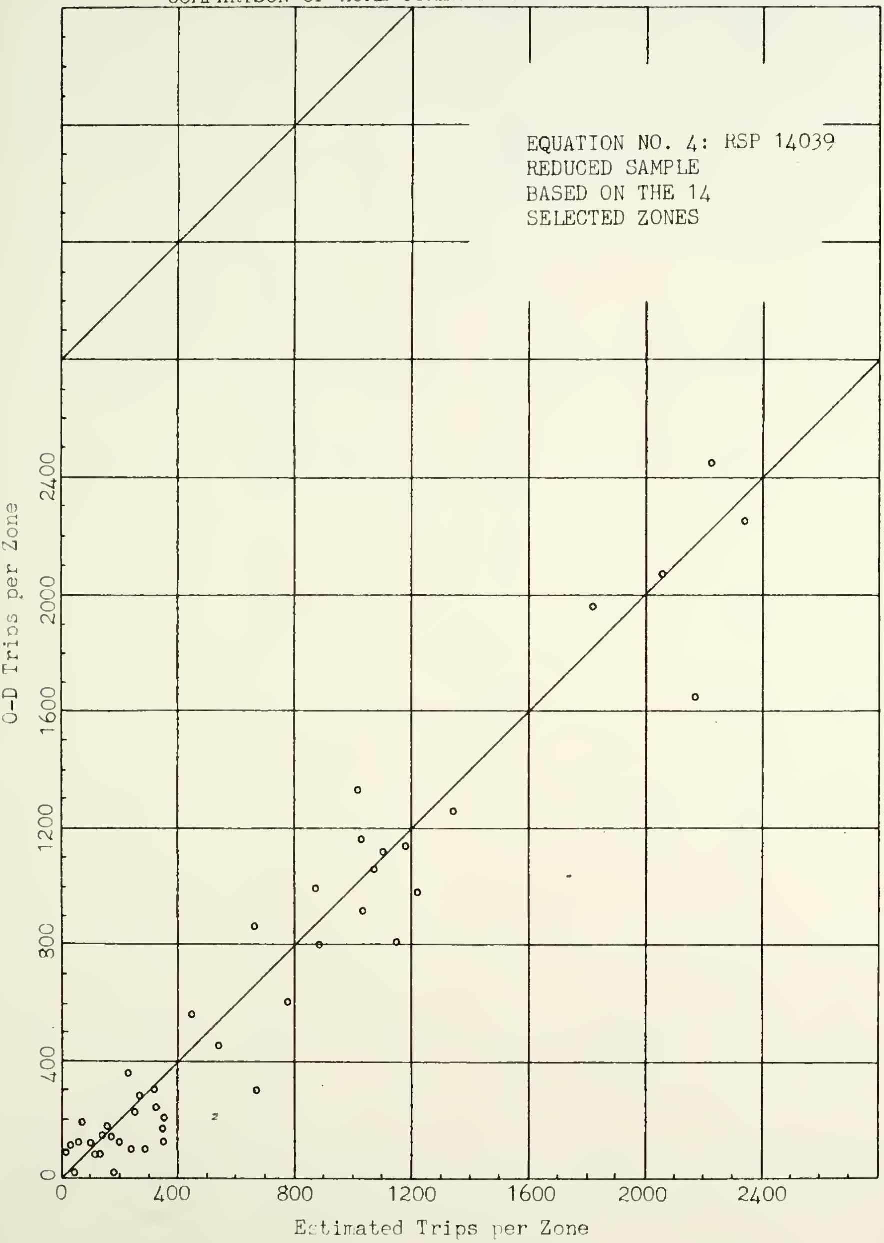


FIGURE 18

COMPARISON OF NON-HOME TRIPS PRODUCED (EQUATION NO. 5)

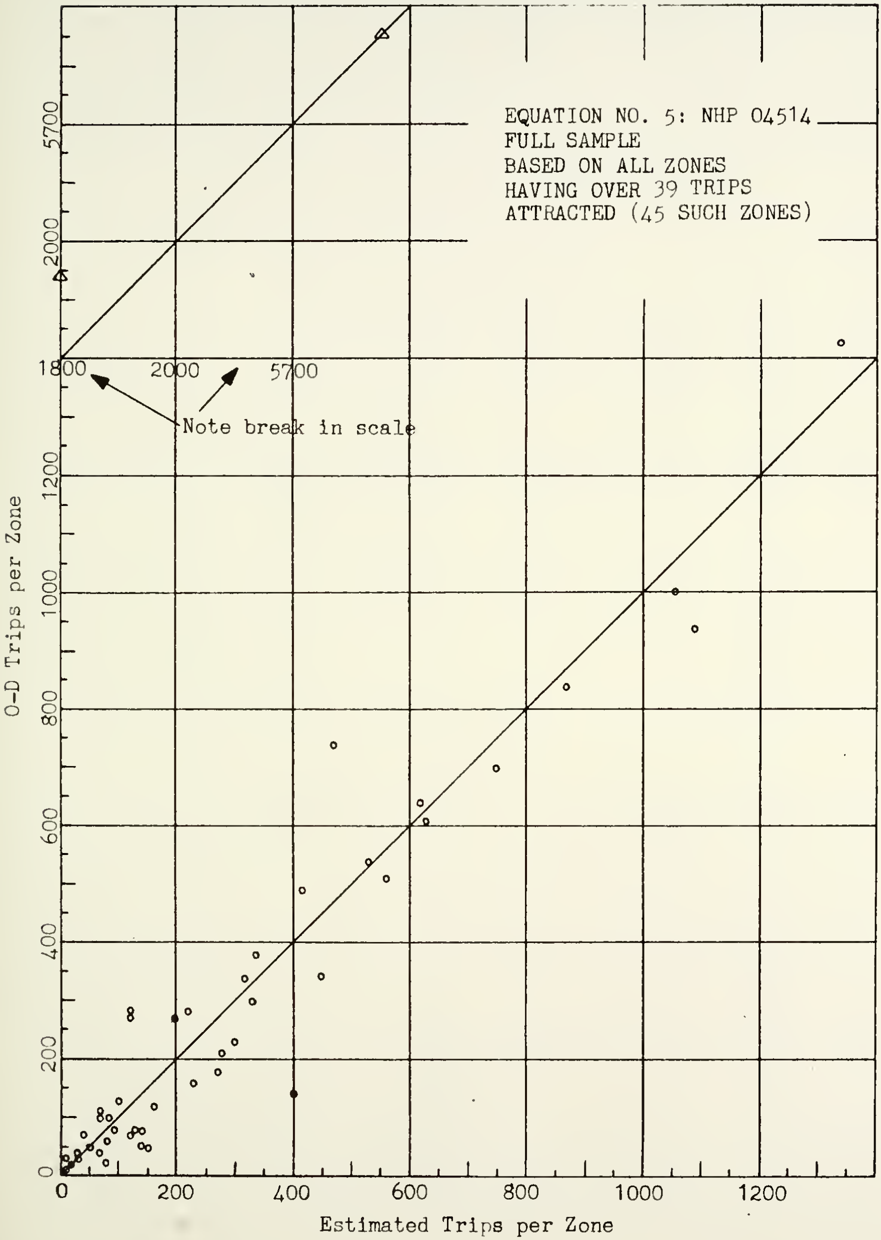


FIGURE 19

COMPARISON OF NON-HOME TRIPS PRODUCED (EQUATION NO. 6)

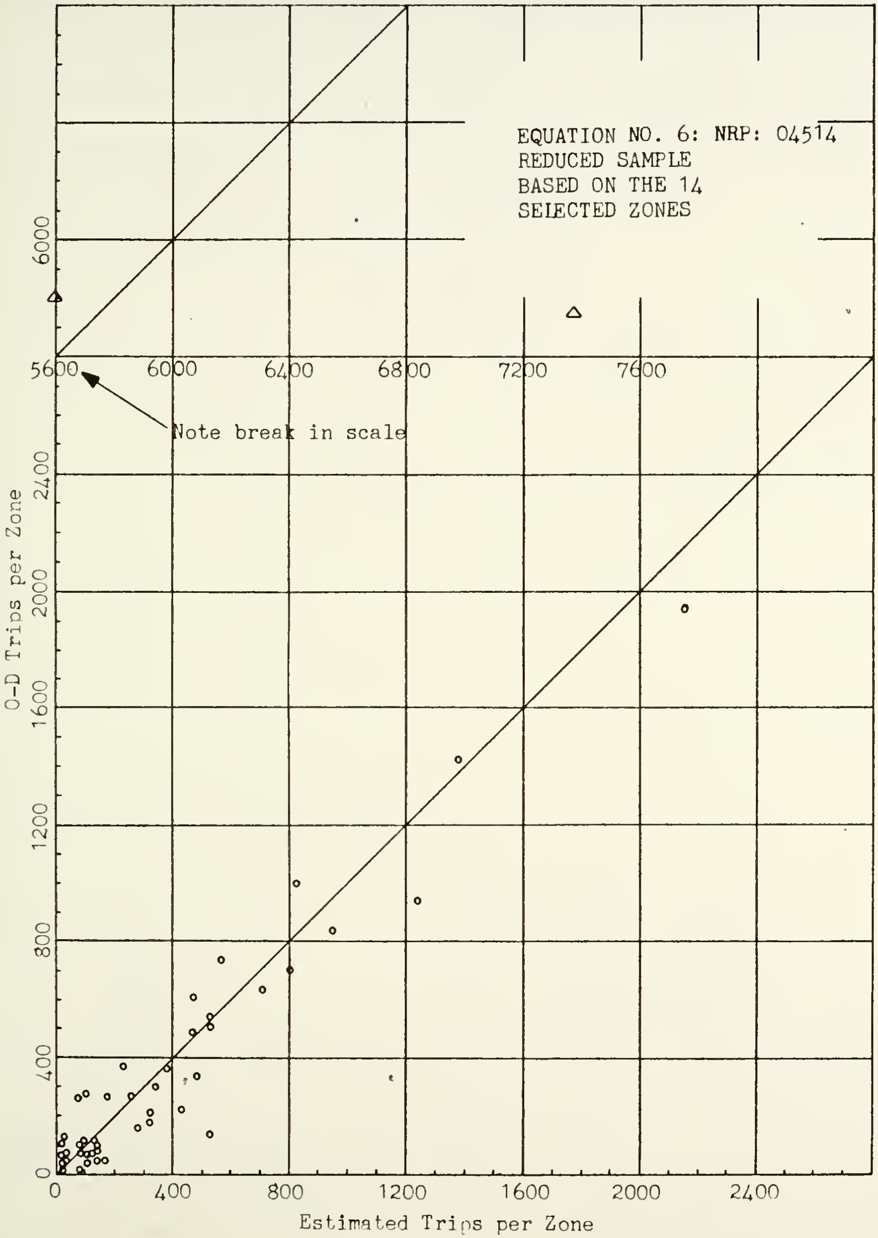


FIGURE 20

COMPARISON OF HOME-WORK TRIPS ATTRACTED (EQUATION NO. 7)

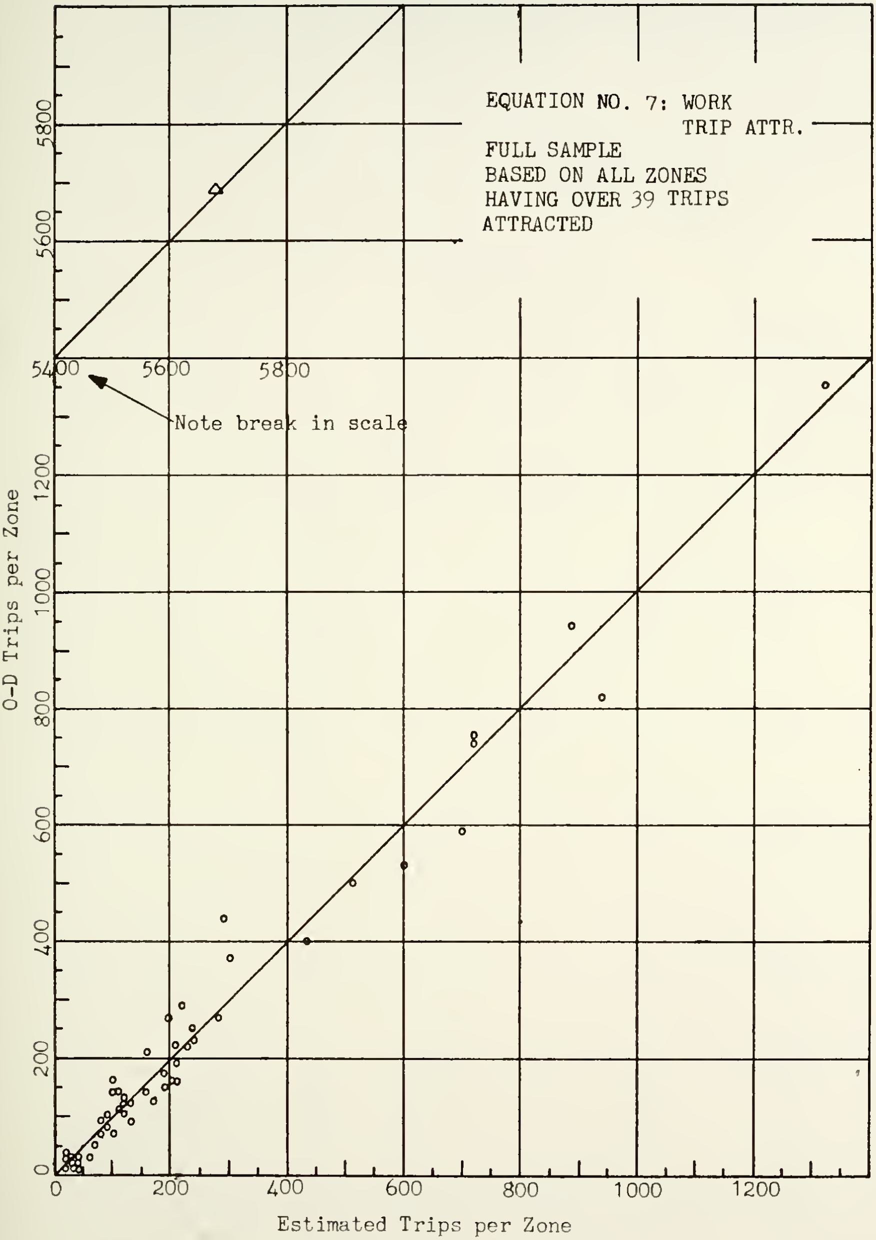


FIGURE 21

COMPARISON OF HOME-WORK TRIPS ATTRACTED (EQUATION NO. 8)

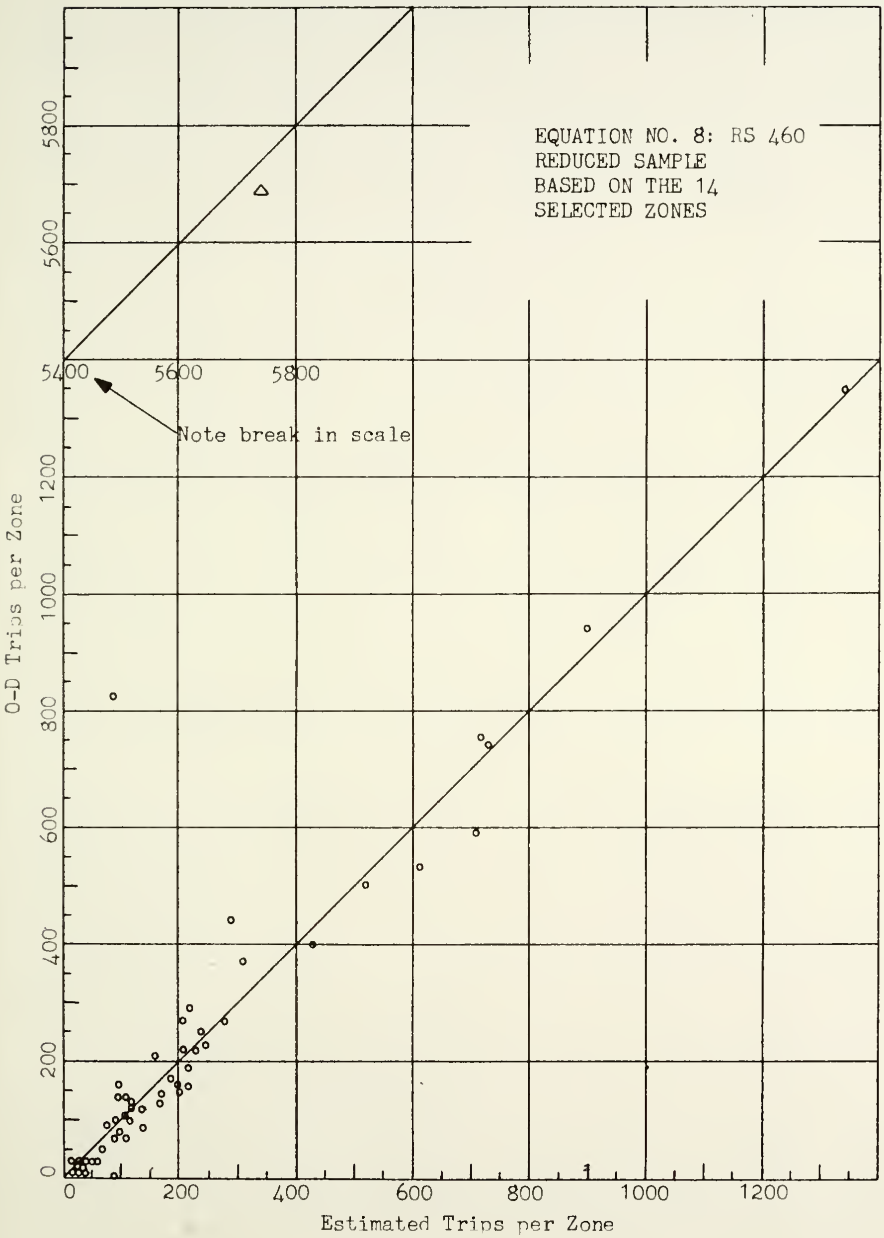


FIGURE 22

COMPARISON OF HOME-OTHER TRIPS ATTRACTED (EQUATION NO. 9)

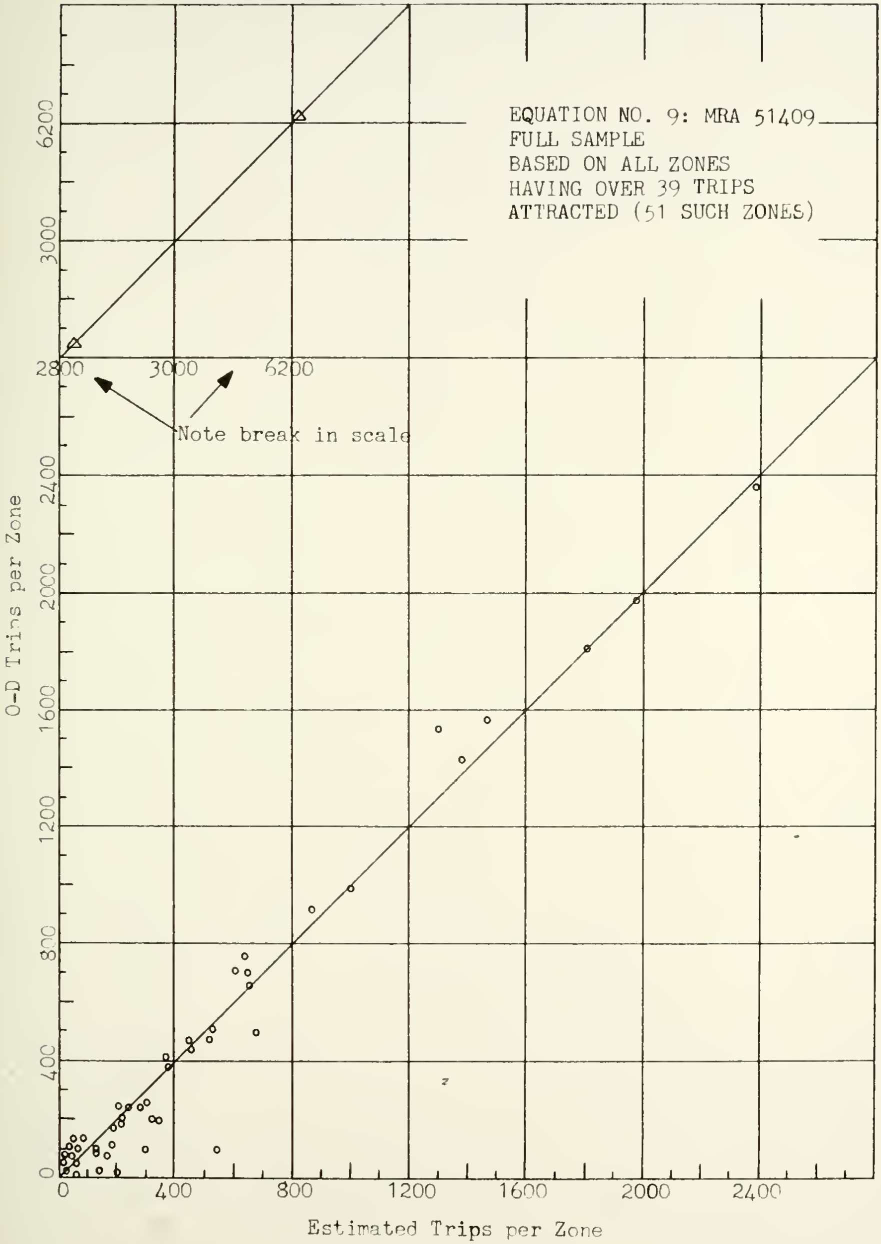


FIGURE 23

COMPARISON OF HOME-OTHER TRIPS ATTRACTED (EQUATION NO. 10)

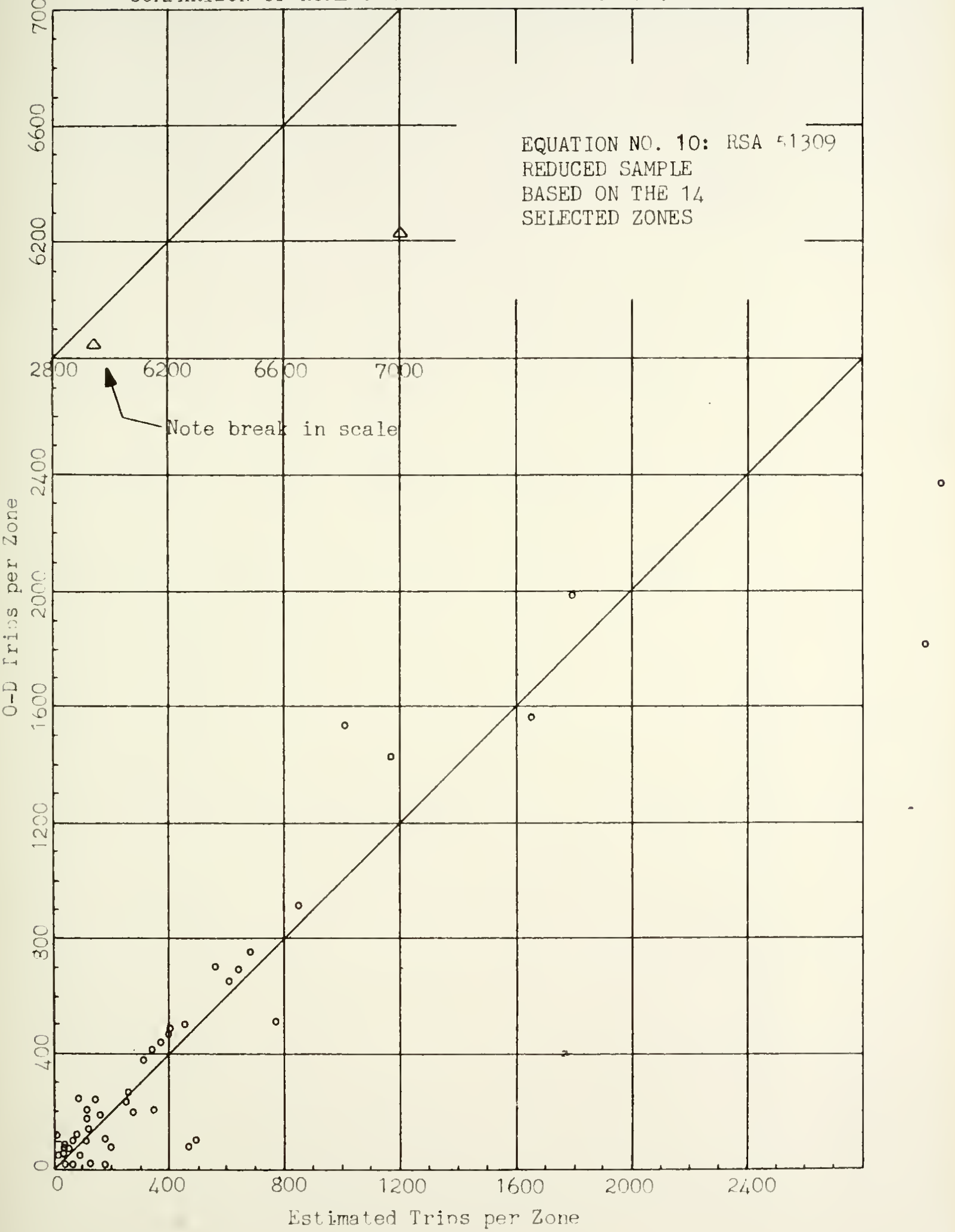


FIGURE 24

COMPARISON OF NON-HOME TRIPS ATTRACTED (EQUATION NO. 11)

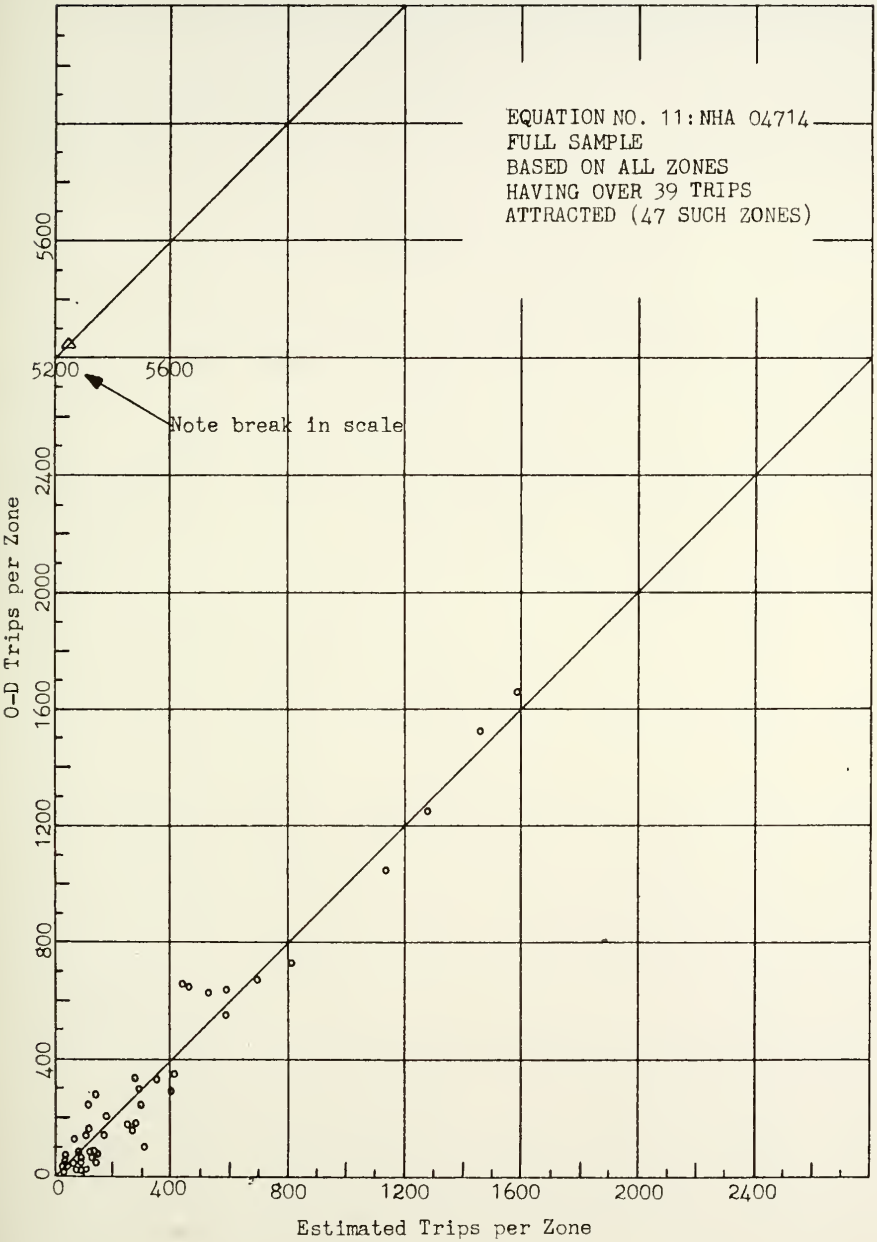
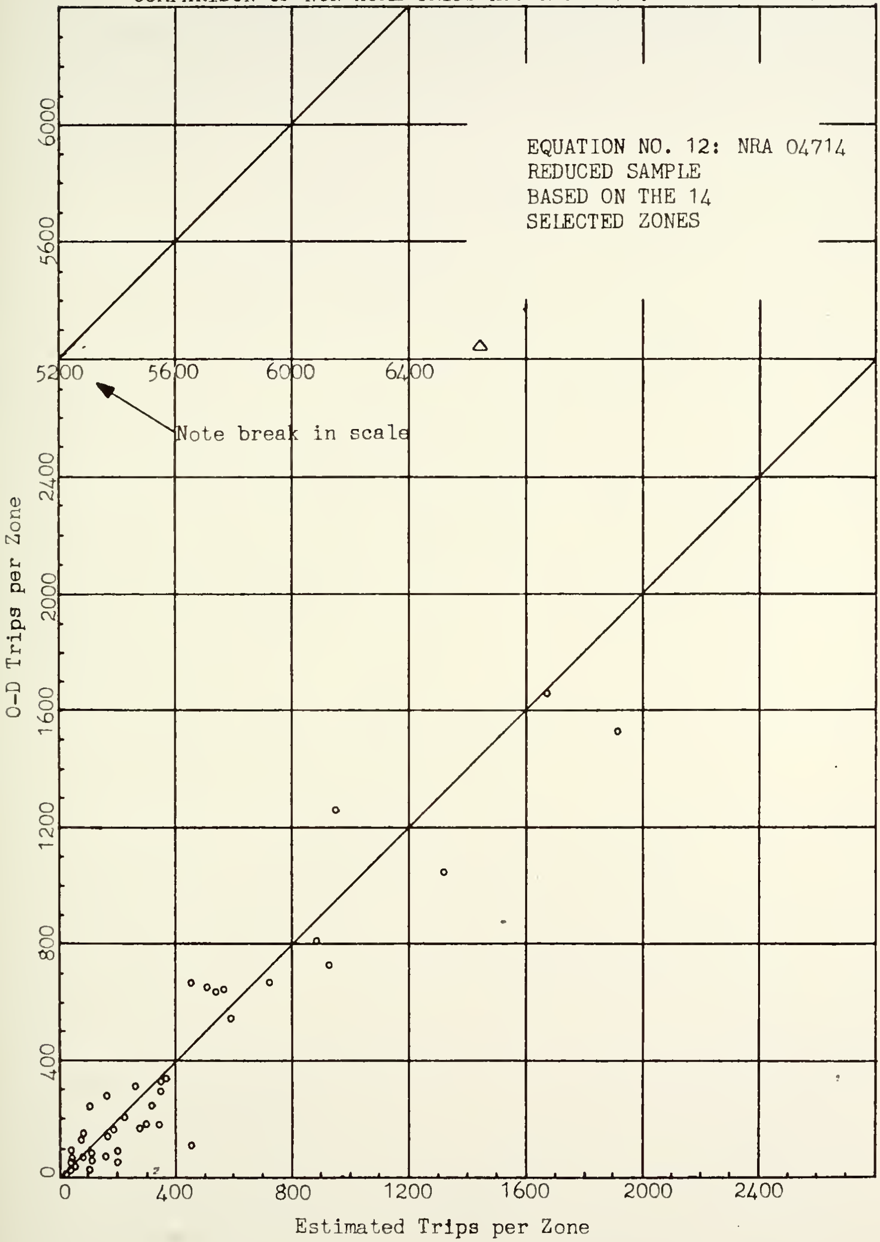


FIGURE 25

COMPARISON OF NON-HOME TRIPS ATTRACTED (EQUATION NO. 12)



Tables 19 through 25 show both the estimated and the O-D values of trip production and attraction by zone and district. The districts were zone groupings used in the analysis of the distribution of trips by the model.

Gravity Model Distribution

As noted, two sets of travel time factors were developed. One set, F_1 , was based upon the O-D productions, attractions and trip length frequency distribution as obtained from the comprehensive O-D data in all zones and the other, F_2 , was based upon productions, attractions and the trip length frequency distribution obtained from the reduced sample in the 14 selected zones. Table 14 shows the developed travel time factors. The trip distribution of the model was analyzed using the following four combinations of model parameters:

Combination 1: O-D productions, attractions, and travel time factors, F_1.

Combination 2: O-D productions, attractions, and travel time factors, F_2.

Combination 3: Estimated productions, attractions, and travel time factors, F_1.

Combination 4: Estimated productions, attractions, and travel time factors, F_2.

Screenline Comparison

Seven "screenlines" were chosen for a comparison of screenline crossings using the O-D data and the crossings obtained from the gravity model with the various combinations of parameters. The location of the various screenlines is shown in Figure 1.

TABLE 19
COMPARISON OF HOME-WORK TRIP PRODUCTION AND ATTRACTION VALUES FROM O-D AND ESTIMATING EQUATIONS
FULL SAMPLE

District	Zone	Full Sample			
		Production		Attraction	
		O-D	Est.	O-D	Est.
1	12	69	78	5688	5675
	13	26	29	751	715
	50	47	-	1346	1321
Sub-Tot		142	107	7785	7711
2	61	548	494	368	304
	62	596	622	104	89
	70	-	-	-	20
Sub-Tot		1144	1116	472	413
3	14	880	812	403	428
Sub-Tot		880	812	403	428
4	23	10	5	269	276
	24	434	439	25	44
	64	734	687	156	195
Sub-Tot		1178	1131	450	515
5	48	10	-	-	20
	49	-	-	-	20
	68	-	-	134	116
	88	5	-	-	20
	89	5	-	-	21
	90	-	-	-	20
	91	-	-	-	22
	92	35	-	-	30
	93	20	-	5	27
	94	10	-	22	37
Sub-Tot		85	-	161	333
6	59	756	750	222	208
	60	1627	1449	250	235
	73	-	-	441	285
	74	934	1103	206	159
Sub-Tot		3317	3302	1119	887
7	76	405	415	106	108
	77	857	745	140	106
	81	34	-	5	33
	82	-	-	-	21
	83	41	-	5	28
Sub-Tot		1337	1160	256	296

District	Zone	Full Sample			
		Production		Attraction	
		O-D	Est.	O-D	Est.
8	15	230	251	25	56
	16	531	517	233	243
	20	-	-	141	102
	21	-	-	15	30
	22	-	-	-	24
	26	-	-	10	20
	27	74	62	10	42
	28	64	42	30	25
	47	-	-	31	20
Sub-Tot		899	872	495	562
9	30	-	-	52	71
	31	-	-	119	122
	32	55	101	71	103
	33	477	461	71	83
	34	36	-	137	164
	35	35	14	134	167
	36	25	71	11	37
	37	-	-	-	20
	38	-	-	5	26
	39	31	69	-	34
	40	15	-	217	228
	41	-	-	-	24
	42	92	155	-	33
	43	10	-	-	25
	44	10	-	-	25
	45	92	71	10	27
	46	10	-	-	20
Sub-Tot		888	942	827	1209
10	17	67	89	193	211
	18	337	323	741	716
	52	-	38	119	133
	54	112	175	36	20
	55	48	113	171	185
	56	177	155	154	193
	78	56	112	-	35
Sub-Tot		797	1005	1414	1493
11	53	1068	913	502	514
Sub-tot		1068	913	502	514

TABLE 19 (Cont.)

District	Zone	Full Sample Production O-D	Full Sample Production Est.	Full Sample Attraction O-D	Full Sample Attraction Est.	District	Zone	Full Sample Production O-D	Full Sample Production Est.	Full Sample Attraction O-D	Full Sample Attraction Est.
12	71	273	165	31	39	15	29	-	-	11	25
	72	86	78	155	98		65	116	101	592	703
	84	102	-	5	28		66	-	-	816	935
	85	51	13	96	115		67	139	80	88	77
	86	-	-	21	42		69	-	-	-	90
	87	104	38	76	87	Sub-Tot		255	181	1669	2044
Sub-Tot		616	294	384	409						
						16	75	931	1006	272	204
13	19	546	556	286	218		79	61	71	11	40
	63	1552	1556	525	600		80	-	-	-	24
Sub-Tot		2098	2112	811	818	Sub-Tot		992	1077	283	268
14	51	1460	1709	938	886	17	57	400	429	92	132
Sub-Tot		1460	1709	938	886		58	578	677	83	94
						Sub-Tot		978	1106	175	226
15	25	-	-	162	214						
						Total		18134	17839	18144	19012

TABLE 20

COMPARISON OF HOME-WORK TRIP PRODUCTION AND ATTRACTION
VALUES FROM O-D AND ESTIMATING EQUATIONS
REDUCED SAMPLE

District	Zone	Reduced Sample				District	Zone	Reduced Sample			
		Production		Attraction				Production		Attraction	
		O-D	Est.	O-D	Est.			O-D	Est.	O-D	Est.
1	12	69	57	5688	5739	8	15	230	572	25	58
	13	26	76	751	724		16	531	659	233	247
	50	47	32	1346	1337		20	-	-	141	104
Sub-Tot		142	165	7785	7800		21	-	-	15	32
							22	-	-	-	25
2	61	548	485	368	309		26	-	-	10	22
	62	596	734	104	91		27	74	69	10	43
	70	-	-	-	22		28	64	56	30	26
Sub-Tot		1144	1219	472	422		47	-	-	31	22
						Sub-Tot		899	1356	495	579
3	14	880	855	403	434						
Sub-Tot		880	855	403	434	9	30	-	-	52	73
							31	-	-	119	124
4	23	10	10	269	280		32	55	86	71	105
	24	434	426	25	46		33	477	536	71	86
	64	734	838	156	199		34	36	-	137	167
Sub-Tot		1178	1274	450	525		35	35	28	134	170
							36	25	36	11	39
5	48	10	-	-	20		37	-	-	-	22
	49	-	-	-	22		38	-	65	5	27
	68	-	-	134	119		39	31	-	-	35
	88	5	-	-	22		40	15	-	217	232
	89	5	-	-	23		41	-	-	-	25
	90	-	-	-	22		42	92	121	-	34
	91	-	-	-	24		43	10	-	-	26
	92	35	-	-	32		44	10	-	-	26
	93	20	-	5	28		45	92	90	10	28
	94	10	-	22	39		46	10	-	-	22
Sub-Tot		85	-	161	351	Sub-Tot		888	962	827	1241
6	59	756	743	222	211	10	17	67	205	193	215
	60	1627	1098	250	239		18	337	765	741	725
	73	-	-	441	289		52	-	62	119	136
	74	934	909	206	162		54	112	204	36	22
Sub-Tot		3317	2750	1119	901		55	48	22	171	188
							56	177	159	154	196
7	76	405	447	106	111		78	56	56	-	36
	77	857	742	140	108	Sub-Tot		797	1473	1414	1518
	81	34	-	5	34						
	82	-	-	-	23	11	53	1068	1040	502	521
	83	41	-	5	30	Sub-Tot		1068	1040	502	521
Sub-Tot		1337	1189	256	306						

TABLE 20 (Cont.)

District	Zone	Reduced Sample			
		Production		Attraction	
		O-D	Est.	O-D	Est.
12	71	273	324	31	41
	72	86	141	155	100
	84	102	166	5	30
	85	51	119	96	118
	86	-	-	21	43
	87	104	118	76	89
Sub-Tot		616	868	384	421
13	19	546	784	286	222
	63	1552	1556	525	608
Sub-Tot		2098	2340	811	830
14	51	1460	1671	938	898
Sub-Tot		1460	1671	938	898
15	25	-	-	162	214
15	29	-	-	11	26
	65	116	132	592	712
	66	-	-	816	94
	67	139	124	88	79
	69	-	-	-	92
Sub-Tot		255	256	1669	1217
16	75	931	1059	272	208
	79	61	52	11	42
	80	-	-	-	25
Sub-Tot		992	1111	283	275
17	57	400	392	92	135
	58	578	640	83	96
Sub-Tot		978	1032	175	231
Total		18134	19561	18144	18470

TABLE 21

COMPARISON OF HOME-OTHER TRIP PRODUCTION AND ATTRACTION VALUES FROM O-D AND ESTIMATING EQUATIONS
FULL SAMPLE

District	Zone	Full Sample Production O-D	Full Sample Production Est.	Full Sample Attraction O-D	Full Sample Attraction Est.
1	12	277	232	6231	6223
	13	117	66	500	679
	50	142	-	2853	2848
Sub-Tot		536	298	9584	9750
2	61	905	960	1533	1303
	62	1055	1136	263	309
	70	-	-	-	-
Sub-Tot		1960	2096	1796	1612
3	14	1326	1488	988	999
Sub-Tot		1326	1488	988	999
4	23	15	8	41	-
	24	803	846	195	226
	64	1138	1045	692	652
Sub-Tot		1956	1899	928	878
5	48	-	-	-	-
	49	-	-	-	-
	68	-	-	113	-
	88	16	-	98	537
	89	45	-	5	-
	90	-	-	15	202
	91	-	-	16	-
	92	55	-	21	-
	93	-	-	-	-
	94	30	-	-	129
Sub-Tot		146	-	268	868
6	59	1116	1110	1432	1384
	60	2888	2344	1568	1468
	73	-	-	753	637
	74	2073	2022	648	658
Sub-Tot		6077	5476	4401	4147
7	76	982	1024	471	450
	77	1956	1594	914	873
	81	15	-	25	-
	82	-	-	-	-
	83	10	-	10	-
Sub-Tot		2963	2618	1420	1323
8	15	558	481	240	238
	16	859	723	379	377
	20	-	-	15	27
	21	-	-	241	279
	22	-	-	88	133
	26	-	-	25	-
	27	135	145	20	138
	28	110	101	75	20
	47	-	-	10	-
Sub-Tot		1662	1450	1093	1212
9	30	-	-	41	-
	31	-	-	100	295
	32	175	177	102	134
	33	985	841	414	370
	34	25	-	697	610
	35	90	12	175	194
	36	76	111	25	18
	37	-	-	-	-
	38	-	-	104	65
	39	81	133	56	25
	40	5	-	-	-
	41	-	-	-	-
	42	127	334	5	20
	43	10	-	-	-
	44	20	-	-	-
	45	122	166	15	6
	46	15	-	5	-
Sub-Tot		1731	1774	1739	1737
10	17	189	81	48	57
	18	447	564	476	521
	52	112	50	102	37
	54	244	326	109	178
	55	116	163	79	169
	56	298	295	46	55
	78	102	283	123	-
Sub-Tot		1508	1762	983	1017
11	53	1259	1272	1808	1806
Sub-Tot		1259	1272	1808	1806

TABLE 21 (Cont.)

District	Zone	Full Sample Production O-D	Full Sample Production Est.	Full Sample Attraction O-D	Full Sample Attraction Est.	District	Zone	Full Sample Production O-D	Full Sample Production Est.	Full Sample Attraction O-D	Full Sample Attraction Est.
12	71	300	645	140	92	15	29	-	-	-	-
	72	364	235	187	207		65	223	217	254	208
	84	200	247	73	48		66	-	-	16	-
	85	204	256	72	9		67	95	224	16	14
	86	-	-	16	64		69	-	-	-	-
	87	174	242	127	53	Sub-Tot		318	441	291	222
Sub-Tot		1242	1625	615	473						
						16	75	1648	1946	514	530
13	19	1164	1179	444	461		79	20	178	10	-
	63	2252	2406	1976	1976		80	-	-	-	-
Sub-Tot		3416	3585	2420	2437	Sub-Tot		1668	2124	524	530
14	51	2451	2622	2374	2393	17	57	597	736	197	354
Sub-Tot		2451	2622	2374	2393		58	811	1038	204	328
						Sub-Tot		1408	1774	401	682
15	25	-	-	5	-						
						Total		31627	32304	31633	32086

TABLE 22

COMPARISON OF HOME-OTHER TRIP PRODUCTION AND ATTRACTION
VALUES FROM O-D AND ESTIMATING EQUATIONS
REDUCED SAMPLE

District	Zone	Reduced Sample			
		Production		Attraction	
		O-D	Est.	O-D	Est.
1	12	277	268	6231	7008
	13	117	63	500	449
	50	142	148	2853	2949
Sub-Tot		536	479	9584	10406
2	61	905	960	1035	1009
	62	1055	1070	263	255
	70	-	-	-	-
Sub-Tot		1960	2030	1298	1264
3	14	1326	1023	988	839
Sub-Tot		1326	1023	988	839
4	23	15	37	41	-
	24	803	892	195	120
	64	1138	1183	692	637
Sub-Tot		1956	2112	928	757
5	48	-	-	-	-
	49	-	-	-	-
	68	-	-	113	-
	88	16	-	98	465
	89	45	-	5	3
	90	-	-	15	184
	91	-	-	16	-
	92	55	-	21	18
	93	-	-	-	6
	94	30	-	-	129
Sub-Tot		146	-	268	805
6	59	1116	1097	1432	1165
	60	2888	2151	1568	1662
	73	-	-	753	675
	74	2073	2062	648	612
Sub-Tot		6077	5310	4401	4114
7	76	982	1218	471	400
	77	1956	1817	914	848
	81	15	-	25	11
	82	-	-	-	8
	83	10	-	10	-
Sub-Tot		2963	3035	1420	1267

District	Zone	Reduced Sample			
		Production		Attraction	
		O-D	Est.	O-D	Est.
8	15	558	450	240	145
	16	859	674	379	314
	20	-	-	15	44
	21	-	-	241	249
	22	-	-	88	39
	26	-	-	25	-
	27	135	172	20	129
	28	110	104	75	43
	47	-	-	10	-
Sub-Tot		1662	1400	1093	963
9	30	-	-	41	-
	31	-	-	100	489
	32	175	156	102	184
	33	985	883	414	342
	34	25	-	697	556
	35	90	25	175	124
	36	76	78	25	8
	37	-	-	-	-
	38	-	-	104	70
	39	81	142	56	34
	40	5	-	-	4
	41	-	-	-	-
	42	127	351	5	8
	43	10	-	-	2
	44	20	-	-	6
	45	122	195	15	27
	46	15	-	5	2
Sub-Tot		1731	1830	1739	1856
10	17	189	65	48	10
	18	447	537	476	399
	52	112	27	102	5
	54	244	328	109	121
	55	116	62	79	203
	56	298	317	46	103
	78	102	285	123	9
Sub-Tot		1508	1621	983	850
11	53	1259	1335	1808	2912
Sub-Tot		1259	1335	1808	2912

TABLE 22 (Cont.)

District	Zone	Reduced Sample				District	Zone	Reduced Sample			
		Production		Attraction				Production		Attraction	
		O-D	Est.	O-D	Est.			O-D	Est.	O-D	Est.
12	71	300	671	140	117	15	29	-	-	-	-
	72	364	334	187	163		65	223	254	248	75
	84	200	351	73	60		66	-	-	16	-
	85	204	351	72	35		67	95	236	16	41
	86	-	-	16	69		69	-	-	-	-
	87	174	351	127	78	Sub-Tot		318	490	285	116
Sub-Tot		1242	2058	615	522						
						16	75	1648	2168	514	768
13	19	1164	1034	444	371		79	20	184	10	5
	63	2252	2341	1976	1797		80	-	-	-	-
Sub-Tot		3416	3375	2420	2168	Sub-Tot		1668	2352	524	773
14	51	2451	2228	2374	3062	17	57	597	783	197	346
Sub-Tot		2451	2228	2374	3062		58	811	1147	204	283
						Sub-Tot		1408	1930	401	629
15	25	-	-	5	-						
						Total		31627	32608	31129	33303

TABLE 23

COMPARISON OF NON-HOME TRIP PRODUCTION AND ATTRACTION VALUES FROM O-D AND ESTIMATING EQUATIONS FULL SAMPLE

District	Zone	Full Sample Production O-D	Production Est.	Attraction O-D	Attraction Est.	District	Zone	Full Sample Production O-D	Production Est.	Attraction O-D	Attraction Est.
1	12	5754	5756	5252	5253	8	15	118	158	154	169
	13	641	615	625	526		16	267	198	211	177
	50	1942	1797	1658	1586		20	31	9	42	-
Sub-Tot		8337	8168	7535	7365		21	52	-	47	-
							22	15	-	20	-
2	61	740	468	652	460		26	5	-	5	-
	62	277	123	277	144		27	25	11	25	35
	70	-	-	-	-		28	10	11	10	27
Sub-Tot		1017	591	929	604		47	-	-	-	-
						Sub-Tot		523	387	514	408
3	14	699	745	732	814						
Sub-Tot		699	745	732	814	9	30	31	-	46	46
							31	57	78	47	91
4	23	72	44	52	62		32	71	118	91	126
	24	108	67	160	118		33	180	273	180	257
	64	283	223	309	292		34	265	117	245	118
Sub-Tot		463	334	521	472		35	127	98	154	113
							36	26	-	21	11
5	48	-	-	-	-		37	-	-	-	-
	49	-	-	-	-		38	10	-	15	-
	68	99	81	88	93		39	5	5	15	31
	88	26	-	36	-		40	52	55	31	109
	89	5	-	10	-		41	-	-	-	-
	90	10	-	15	-		42	31	34	26	68
	91	-	-	5	-		43	-	-	-	-
	92	5	-	15	23		44	-	-	-	-
	93	-	-	-	-		45	41	28	66	43
	94	5	-	5	-		46	-	-	-	-
Sub-Tot		150	81	174	116	Sub-Tot		896	806	937	1013
6	59	540	527	638	590	10	17	102	71	67	33
	60	606	628	668	702		18	836	866	814	812
	73	340	447	303	398		52	82	131	76	93
	74	509	559	545	591		54	36	68	47	37
Sub-Tot		1995	2161	2154	2281		55	77	142	83	150
							56	67	123	88	117
7	76	230	299	183	282		78	36	-	20	27
	77	493	418	658	438	Sub-Tot		1236	1401	1195	1269
	81	20	-	20	4						
	82	5	-	5	-	11	53	938	1091	1051	1138
	83	5	-	-	8	Sub-Tot		938	1091	1051	1138
Sub-Tot		753	717	866	732						

TABLE 23 (Cont.)

District	Zone	Full Sample Production O-D	Full Sample Production Est.	Full Sample Attraction O-D	Full Sample Attraction Est.	District	Zone	Full Sample Production O-D	Full Sample Production Est.	Full Sample Attraction O-D	Full Sample Attraction Est.
12	71	47	149	47	140	15	29	5	-	5	-
	72	103	88	134	67		65	366	324	341	281
	84	20	37	36	4		66	140	399	107	313
	85	52	138	67	125		67	76	93	61	92
	86	5	-	11	3		69	-	-	-	-
	87	20	83	25	92	Sub-Tot		639	816	556	686
Sub-Tot		247	495	320	431						
						16	75	374	339	363	414
13	19	304	326	342	349		79	31	-	26	23
	63	999	1062	1251	1283		80	-	-	-	-
Sub-Tot		1303	1388	1593	1632	Sub-Tot		405	339	389	437
14	51	1433	1340	1528	1461	17	57	162	232	172	265
Sub-Tot		1433	1340	1528	1461		58	214	278	246	296
						Sub-Tot		376	510	418	561
15	25	52	-	42	-						
						Total		21410	21370	21412	21420

TABLE 24

COMPARISON OF NON-HOME TRIP PRODUCTION AND ATTRACTION
VALUES FROM O-D AND ESTIMATING EQUATIONS
REDUCED SAMPLE

District	Zone	Reduced Sample				District	Zone	Reduced Sample			
		Production		Attraction				Production		Attraction	
		O-D	Est.	O-D	Est.			O-D	Est.	O-D	Est.
1	12	5754	7374	5252	6647	8	15	118	95	154	173
	13	641	706	625	537		16	267	257	211	216
	50	1942	2162	1658	1674		20	31	21	42	-
Sub-Tot		8337	10242	7535	8858		21	52	-	47	-
							22	15	-	20	-
2	61	740	572	652	508		26	5	-	5	-
	62	277	95	277	165		27	25	11	25	9
	70	-	-	-	-		28	10	11	10	15
Sub-Tot		1017	667	929	673		47	-	-	-	-
						Sub-Tot		523	395	514	413
3	14	699	804	732	930						
Sub-Tot		699	804	732	930	9	30	31	-	46	-
							31	57	21	47	9
4	23	72	38	52	8		32	71	99	91	103
	24	108	132	160	178		33	180	323	180	303
	64	283	166	309	263		34	265	75	245	96
Sub-Tot		463	336	521	449		35	127	34	154	82
							36	26	-	21	-
5	48	-	-	-	-		37	-	-	-	-
	49	-	-	-	-		38	10	-	15	-
	68	1942	2162	1658	1674		39	5	5	15	31
	88	26	-	36	-		40	52	38	31	60
	89	5	-	10	-		41	-	-	-	-
	90	10	-	15	-		42	31	35	26	25
	91	-	-	5	-		43	-	-	-	-
	92	5	-	15	23		44	-	-	-	-
	93	-	-	-	-		45	41	28	66	39
	94	5	-	5	-		46	-	-	-	-
Sub-Tot		1993	2162	1744	1697	Sub-Tot		896	658	937	748
6	59	540	533	638	571	10	17	102	81	67	-
	60	606	469	668	716		18	836	953	814	888
	73	340	483	303	353		52	82	142	76	76
	74	509	528	545	594		54	36	114	47	36
Sub-Tot		1995	2013	2154	2234		55	77	142	83	109
							56	67	116	88	201
7	76	230	429	183	349		78	36	-	20	0
	77	493	471	658	458	Sub-Tot		1236	1548	1195	1310
	81	20	-	20	4						
	82	5	-	5	-	11	53	938	1235	1051	1322
	83	5	-	-	8	Sub-Tot		938	1235	1051	1322
Sub-Tot		753	900	866	819						

TABLE 24 (Cont.)

District	Zone	Reduced Sample				District	Zone	Reduced Sample			
		Production		Attraction				Production		Attraction	
		O-D	Est.	O-D	Est.			O-D	Est.	O-D	Est.
12	71	47	169	47	203	15	39	5	-	5	-
	72	103	142	134	75		65	366	379	341	354
	84	20	80	36	50		66	140	534	107	453
	85	52	159	67	163		67	76	79	61	109
	86	5	-	11	-		69	-	-	-	-
	87	20	84	25	95	Sub-Tot		639	992	551	916
Sub-Tot		247	634	320	586						
						16	75	374	226	363	360
13	19	304	343	342	361		79	31	-	26	-
	63	999	830	1251	952		80	-	-	-	-
Sub-Tot		1303	1173	1593	1313	Sub-Tot		405	226	389	360
14	51	1433	1394	1528	1915	17	57	162	276	172	281
Sub-Tot		1433	1394	1528	1915		58	214	323	246	316
						Sub-Tot		376	599	418	597
15	25	52	-	42	-						
						Total		23253	25978	22977	25140

TABLE 25

COMPARISON OF NON-HOME TRIP PRODUCTION AND ATTRACTION
VALUES FROM O-D AND ESTIMATING EQUATIONS
REDUCED SAMPLE (Adjusted)*

District	Zone	Reduced Sample (Adjusted)* Production O-D	Production Est.	Attraction O-D	Attraction Est.
1	12	5754	6706	5252	6045
	13	641	642	625	488
	50	1942	1966	1658	1522
Sub-Tot		8337	9314	7535	8055
2	61	740	520	652	462
	62	277	86	277	150
	70	-	-	-	-
Sub-Tot		1017	606	929	612
3	14	699	731	732	846
Sub-Tot		699	731	732	846
4	23	72	35	52	7
	24	108	120	160	162
	64	283	151	309	239
Sub-Tot		463	306	521	408
5	48	-	-	-	-
	49	-	-	-	-
	68	99	19	88	38
	88	26	-	36	-
	89	5	-	10	-
	90	10	-	15	-
	91	-	-	5	-
	92	5	-	15	-
	93	-	-	-	-
	94	5	-	5	-
Sub-Tot		150	19	174	38
6	59	540	485	638	519
	60	606	427	668	651
	73	340	439	303	321
	74	509	480	545	540
Sub-Tot		1995	1831	2154	2031
7	76	230	390	183	317
	77	493	428	658	417
	81	20	-	20	-
	82	5	-	5	-
	83	5	-	-	-
Sub-Tot		753	818	866	734
8	15	118	86	154	157
	16	267	234	211	196
	20	31	19	42	-
	21	52	-	47	-
	22	15	-	20	-
	26	5	-	5	-
	27	25	-	25	8
	28	10	-	10	14
	47	-	-	-	-
Sub-Tot		523	339	514	375
9	30	31	-	46	-
	31	57	19	47	8
	32	71	90	91	94
	33	180	294	180	276
	34	265	68	245	87
	35	127	31	154	75
	36	26	-	21	-
	37	-	-	-	-
	38	10	-	15	-
	39	5	-	15	4
	40	52	35	31	55
	41	-	-	-	-
	42	31	32	26	23
	43	-	-	-	-
	44	-	-	-	-
	45	41	-	66	35
	46	-	-	-	-
Sub-Tot		896	569	937	657
10	17	102	74	67	-
	18	836	867	814	808
	52	82	129	76	69
	54	36	104	47	33
	55	77	120	83	99
	56	67	105	88	183
	78	36	-	20	-
Sub-Tot		1236	1399	1195	1192
11	53	938	1123	1051	1202
Sub-Tot		938	1123	1051	1202

TABLE 25 (Cont.)

District	Zone	Reduced Sample (Adjusted)*			
		Production		Attraction	
		O-D	Est.	O-D	Est.
12	71	47	154	47	185
	72	103	129	134	68
	84	20	73	36	45
	85	52	145	67	148
	86	5	-	11	-
	87	20	76	25	86
Sub-Tot		247	577	320	532
13	19	304	312	342	328
	63	999	755	1251	866
Sub-Tot		1303	1067	1593	1194
14	51	1433	1268	1528	1742
Sub-Tot		1433	1268	1528	1742
15	25	52	-	42	6

District	Zone	Reduced Sample (Adjusted)*			
		Production		Attraction	
		O-D	Est.	O-D	Est.
15	29	5	-	5	-
	65	366	345	341	322
	66	140	486	107	412
	67	76	72	61	99
	69	99	-	88	-
Sub-Tot		738	903	644	839
16	75	374	206	363	327
	79	31	-	26	-
	80	-	-	-	-
Sub-Tot		405	206	389	327
17	57	162	251	172	256
	58	214	294	246	287
Sub-Tot		376	545	418	543
Total		21509	21621	21500	21327

* O-D total non-home productions and attractions were used to expand to zonal totals. In Table 24 estimated total non-home productions and attractions were used.

Crossings of screenline 6 showed the largest per cent difference; however, the number of trips crossing the line was very small making it difficult to obtain a close agreement, percentage wise. It is believed, however, that this did indicate some geographical bias in the model and could probably have been remedied by increasing the terminal times in the zones south of screenline 6 or by applying zone to zone "k" factors. The total number of trips, however, involved did not appear to warrant such adjusting procedures. Tables 26 through 29 compare the various screenline crossings.

Trip Length Comparison

It was felt that the comparison of the total amount of travel and average trip length as obtained from the various model distributions would serve as measurements of the adequacy of the model.

Figures 26 through 37 show the trip length frequency distribution, by purpose, of the O-D data versus the various model configurations. These comparisons show a very close agreement of the model and O-D data.

The comparisons of the average length of trip in minutes and total vehicle hours of travel are shown in Tables 30 and 31 and also indicate close agreement. The comparisons of the average length of trip in miles and total vehicle miles of travel are shown in Tables 32 and 33 and again indicate close agreement.

Since there were few diagonal streets in Hutchinson, the distance, in miles, between zone centroids was measured by determining the "L" distance (sum of map coordinate differences) and the total

TABLE 26

COMPARISON OF SCREENLINE CROSSINGS OF ALL TRIPS USING O-D AND MODEL DATA

Screen-line	Crossings from Complete O-D Survey	Full Sample/1				Reduced Sample /2			
		Model /3 F_1	Model / O-D (%)	Model /4 F_2	Model / O-D (%)	Model /3 F_1	Model / O-D (%)	Model /4 F_2	Model / O-D (%)
1/5	27564	27478	99.7	29924	108.6	27861	101.1	29884	108.4
2	20557	20946	101.9	21930	106.7	21157	102.7	22212	108.1
3	27656	26439	95.6	28248	102.1	26678	96.5	28505	103.1
4	24530	24008	97.9	25299	103.1	24240	98.8	25473	103.8
5	26828	24765	92.3	28643	106.8	26419	98.5	28536	106.4
6	4202	5156	122.7	5720	136.1	5095	121.3	5704	135.7
7	10028	9682	96.5	11302	112.7	9734	97.1	11755	117.2
Total	141365	138474	98.0	151066	106.9	141184	99.9	152069	107.6

1/ Using productions and attractions from the complete O-D survey.

2/ Using productions and attractions obtained from the regression estimating equations developed from the reduced sample in the 14 selected zones.

3/ Using travel time factors developed with model input productions and attractions from the complete O-D survey.

4/ Using travel time factors developed with model input productions and attractions from the 14 zones with a reduced sample size.

[illegible]

TABLE 27

COMPARISON OF SCREENLINE CROSSINGS OF HOME-WORK TRIPS USING O-D AND MODEL DATA

Screen-line	Crossings from Complete O-D Survey	Full Sample/1				Reduced Sample /2			
		Model /3 F_1	Model / O-D (%)	Model /4 F_2	Model / O-D (%)	Model /3 F_1	Model / O-D (%)	Model /4 F_2	Model / O-D (%)
1/5	8507	8731	102.6	9537	112.1	8793	103.4	9438	110.9
2	6140	6229	101.4	6762	110.1	6328	103.1	6990	113.8
3	8908	8245	92.6	8427	94.6	8320	93.4	8565	96.1
4	7714	7535	97.7	7566	98.1	7609	98.6	7642	99.1
5	7844	7644	97.5	8339	106.3	7642	97.4	8007	102.1
6	1235	1427	115.5	1838	148.8	1450	117.4	1839	148.9
7	3596	3440	95.7	3672	102.1	3522	97.9	4194	116.6
Total	43944	43251	98.4	46141	105.0	43664	99.4	46675	106.2

1/ Using productions and attractions from the complete O-D survey.
2/ Using productions and attractions obtained from the regression estimating equations developed from the reduced sample in the 14 selected zones.
3/ Using travel time factors developed with model input productions and attractions from the complete O-D survey.
4/ Using travel time factors developed with model input productions and attractions from the 14 zones with a reduced sample size.
5/ Figure [illegible]

TABLE 28

COMPARISON OF SCREENLINE CROSSINGS OF HOME-OTHER TRIPS USING O-D AND MODEL DATA

Screen-line	Crossings from Complete O-D Survey	Full Sample/1				Reduced Sample /2			
		Model /3 F_1	$\frac{\text{Model}}{\text{O-D}}$ (%)	Model /4 F_2	$\frac{\text{Model}}{\text{O-D}}$ (%)	Model /3 F_1	$\frac{\text{Model}}{\text{O-D}}$ (%)	Model /4 F_2	$\frac{\text{Model}}{\text{O-D}}$ (%)
1/5	9959	9916	99.6	10275	103.2	10007	100.5	10332	103.7
2	9002	9182	102.0	9784	108.2	9292	103.2	9840	109.3
3	11694	11289	96.5	12518	107.0	11450	97.9	12634	108.0
4	10509	10342	98.4	11464	110.8	10500	99.9	11569	110.1
5	9785	9388	95.9	9840	100.6	9605	98.2	10073	102.9
6	1731	2130	123.1	2274	131.4	2128	122.9	2256	130.3
7	4239	4077	96.2	4971	117.3	4045	95.4	4902	115.6
Total	56919	56324	99.0	61126	107.4	57027	100.2	61606	108.2

1/ Using productions and attractions from the complete O-D survey.
2/ Using productions and attractions obtained from the regression estimating equations developed from the reduced sample in the 14 selected zones.
3/ Using travel time factors developed with model input productions and attractions from the complete O-D survey.
4/ Using travel time factors developed with model input productions and attractions from the 14 zones with a reduced sample size.
5/ See Figure 1 for the locations of screenlines.

TABLE 29

COMPARISON OF SCREENLINE CROSSINGS OF NON-HOME TRIPS USING O-D AND MODEL DATA

Screen-line	Crossings from Complete O-D Survey	Full Sample/1				Reduced Sample /2			
		Model /3 F_1	Model / O-D (%)	Model /4 F_2	Model / O-D (%)	Model /3 F_1	Model / O-D (%)	Model /4 F_2	Model / O-D (%)
1/5	9098	9055	99.5	10112	111.1	9061	99.6	10114	111.2
2	5415	5535	102.2	5385	99.4	5538	102.3	5383	99.4
3	7054	6905	97.9	7304	103.5	6908	97.9	7305	103.6
4	6309	6131	97.2	6271	99.4	6131	97.2	6262	99.3
5	9198	9161	99.6	10465	113.8	9172	99.7	10436	113.7
6	1235	1515	122.7	1608	130.2	1513	122.9	1509	130.3
7	2193	2155	[illegible]	[illegible]	121.3	2157	98.6	2659	121.2
Total	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]495	[illegible]	[illegible]	[illegible]

1/ Using produ[illegible] from the co[illegible] O-D survey.
2/ Using productions [illegible] from [illegible] estimating [illegible] the reduced sample in the [illegible] zones.
3/ Using travel [illegible] factors [illegible] with model in [illegible] the sample O-D survey.
4/ Using travel time factors developed with model [illegible] attractions [illegible] in the 14 zones with a reduced sample size.
5/ See Figure [illegible] locations of screenlines.

FIGURE 26

COMPARISON OF TRIP LENGTH FREQUENCY USING O-D AND ...

HOME-WORK TRIPS - COMBINATION 1 PARAMETER

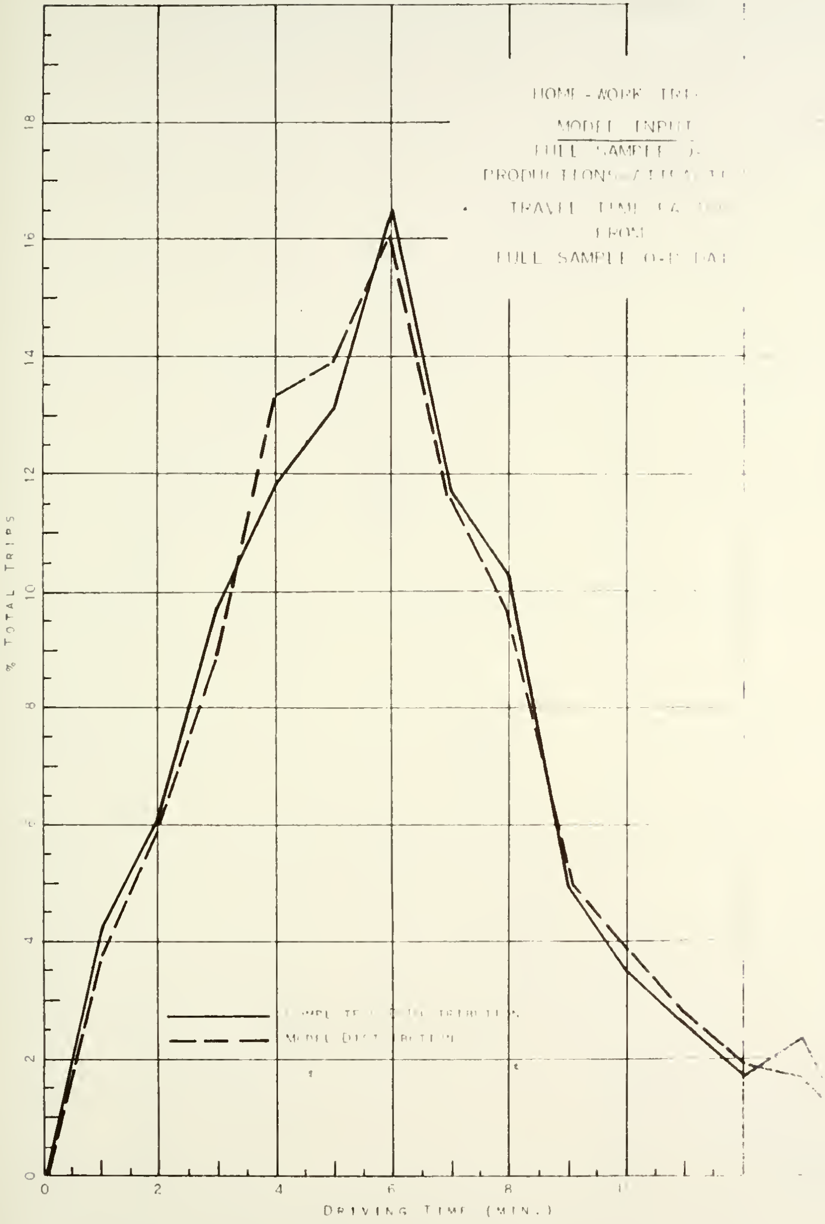


FIGURE 27

COMPARISON OF TRIP LENGTH FREQUENCY USING O-D AND MODEL DATA
HOME-OTHER TRIPS - COMBINATION 1 PARAMETERS

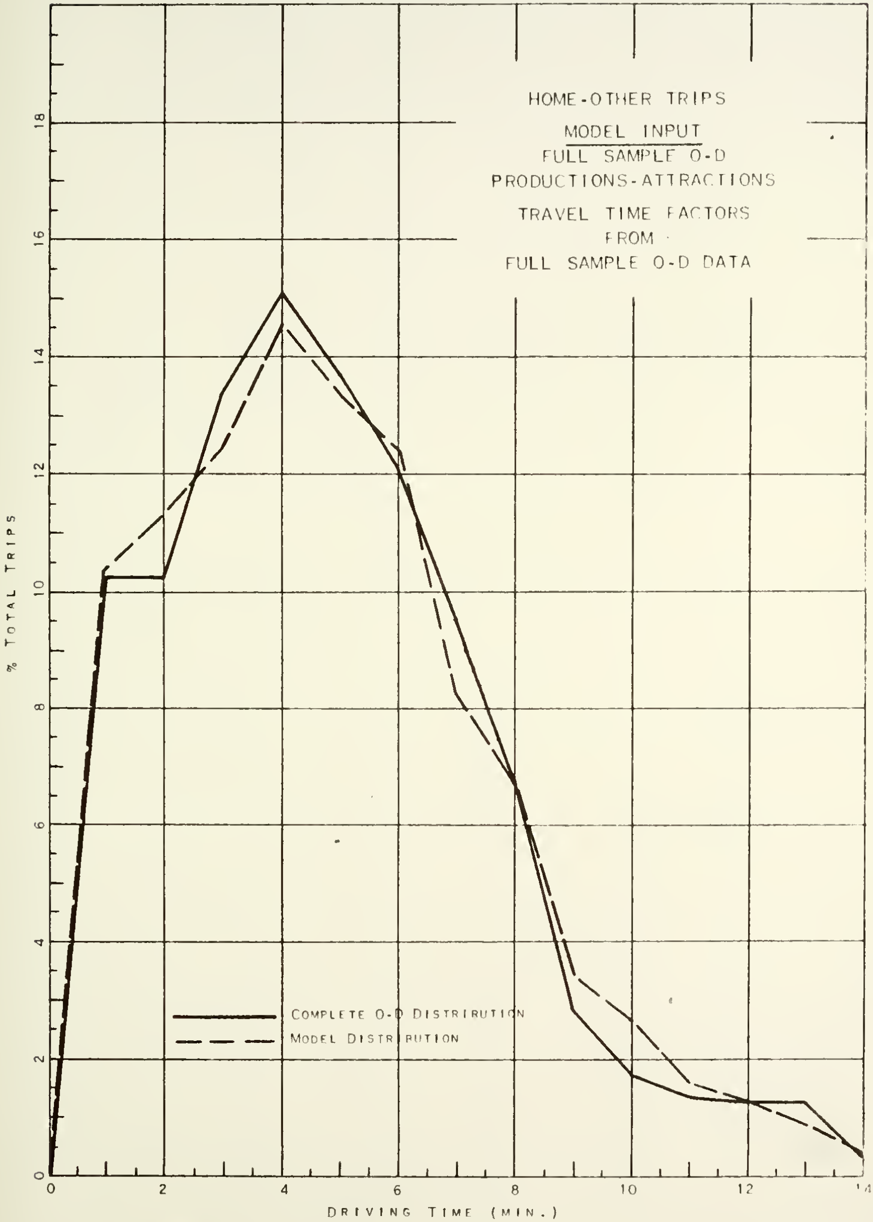


FIGURE 28

COMPARISON OF TRIP LENGTH FREQUENCY USING O-D AND MO

NON-HOME TRIPS - COMBINATION 1 PARAMETERS

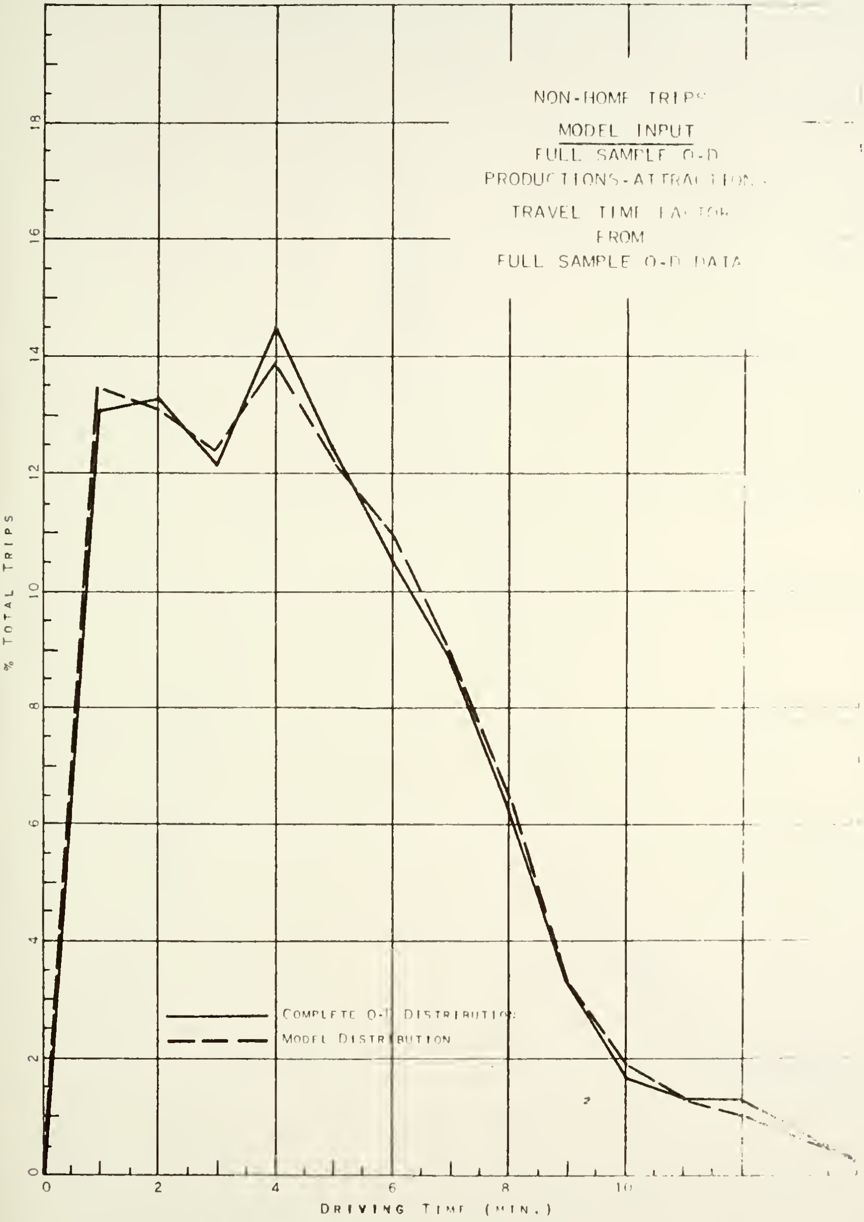


FIGURE 29

COMPARISON OF TRIP LENGTH FREQUENCY USING O-D AND MODEL DATA

HOME-WORK TRIPS - COMBINATION 2 PARAMETERS

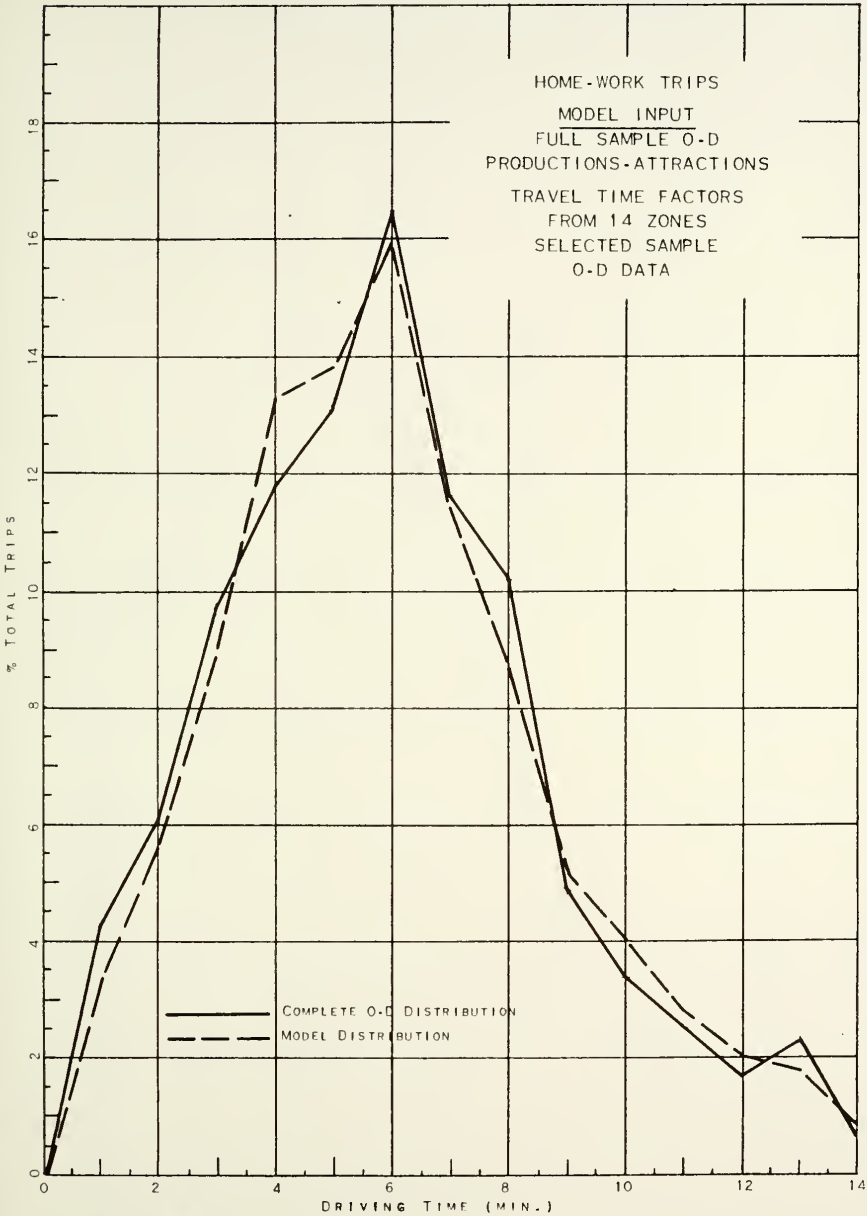


FIGURE 30

COMPARISON OF TRIP LENGTH FREQUENCY USING O-D AND MODEL DATA

HOME-OTHER TRIPS - COMBINATION 2 PARAMETERS

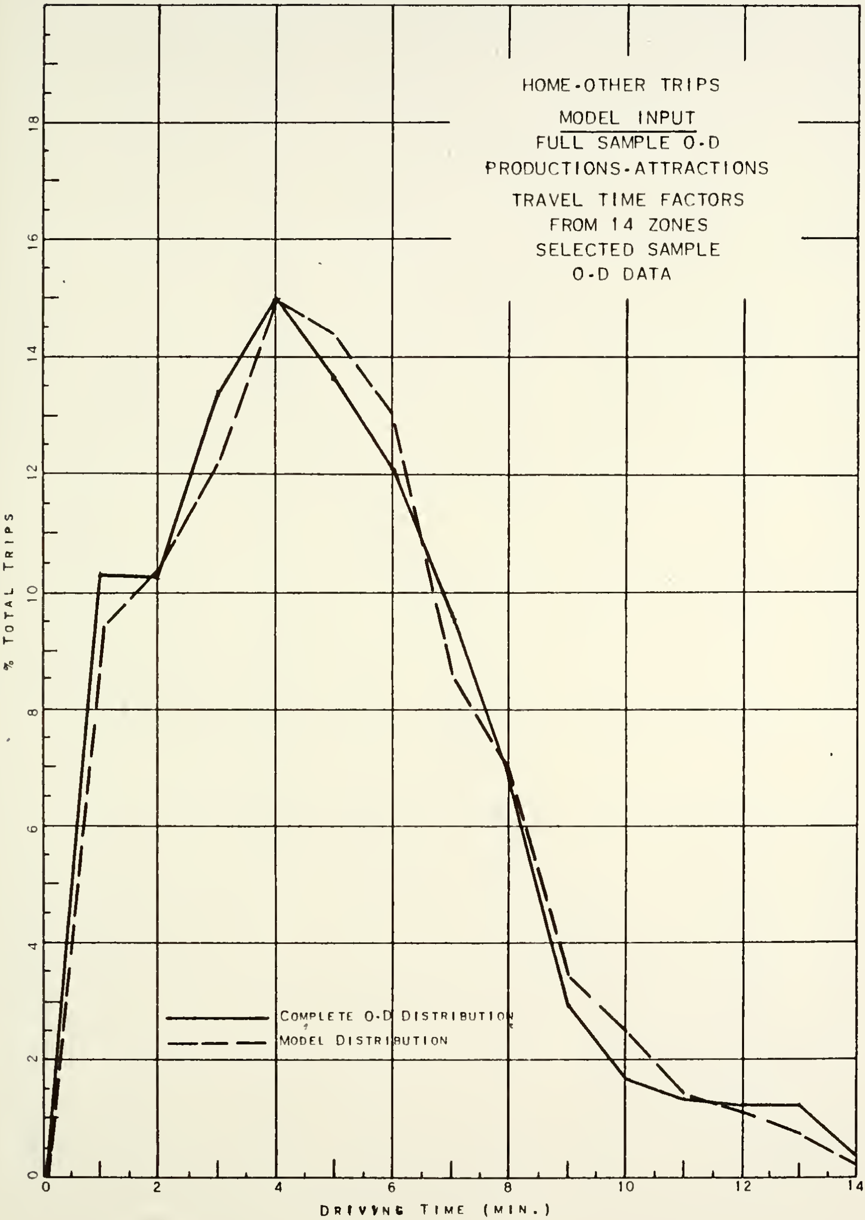


FIGURE 31

COMPARISON OF TRIP LENGTH FREQUENCY USING O-D AND MODEL DATA

NON-HOME TRIPS - COMBINATION 2 PARAMETERS

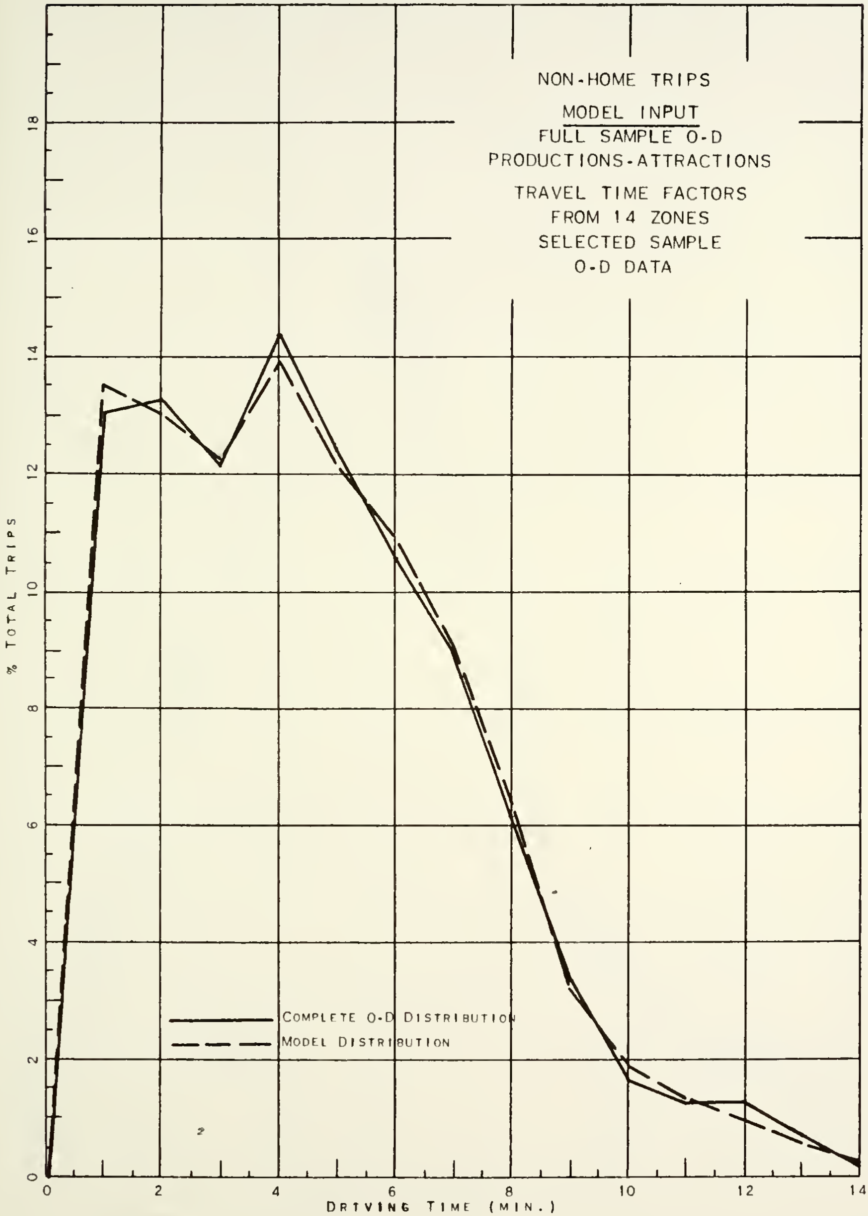


FIGURE 32

COMPARISON OF TRIP LENGTH FREQUENCY USING O-D AND MODEL DATA

HOME-WORK TRIPS - COMBINATION 3 PARAMETERS

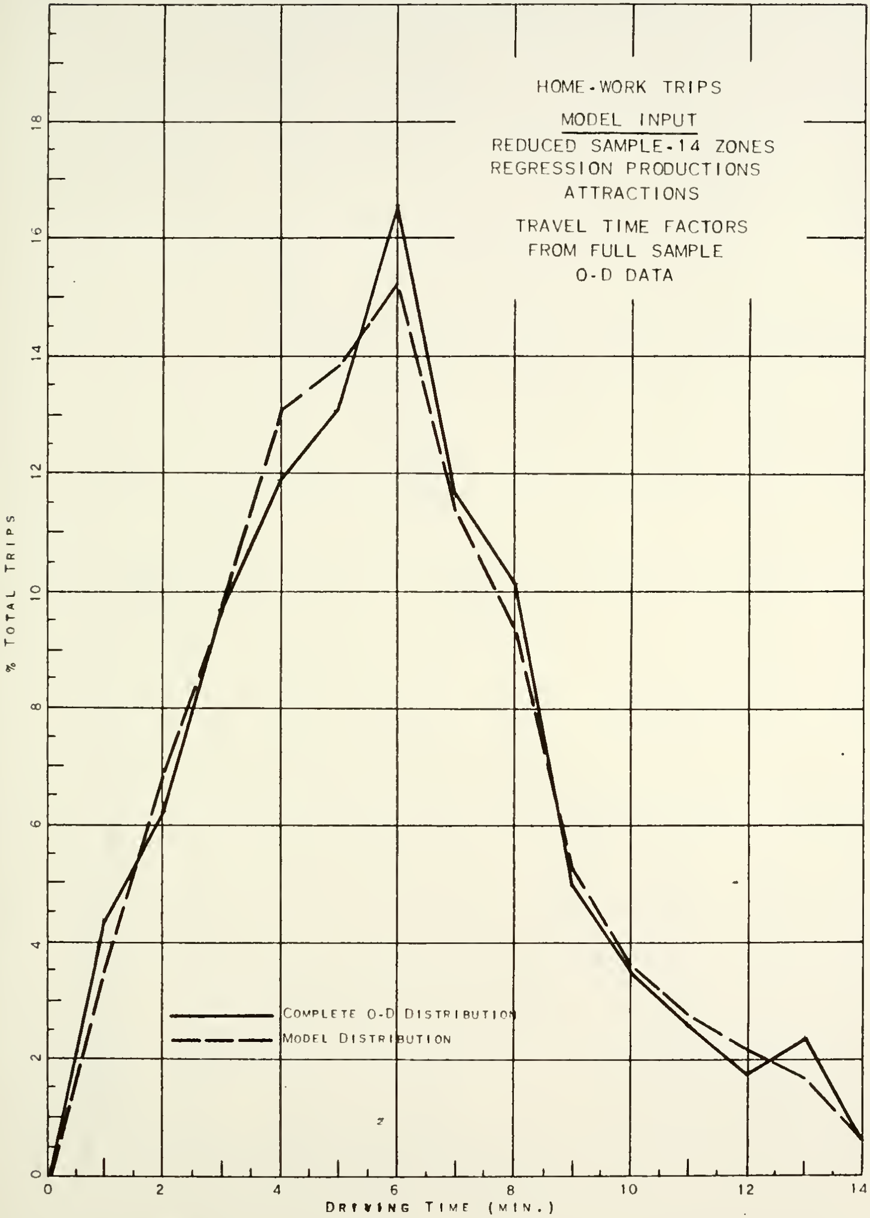


FIGURE 33

COMPARISON OF TRIP LENGTH FREQUENCY USING O-D AND MODEL DATA

HOME-OTHER TRIPS - COMBINATION 3 PARAMETERS

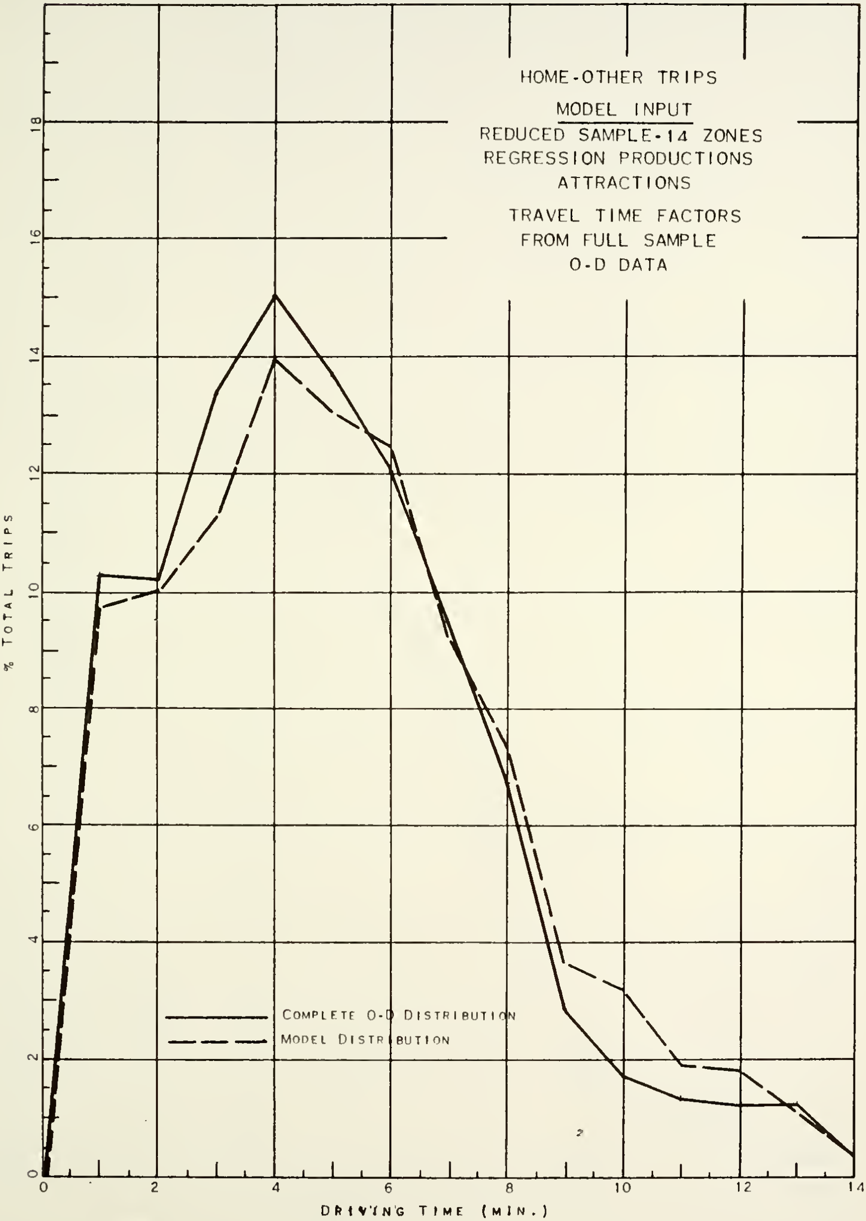


FIGURE 34

COMPARISON OF TRIP LENGTH FREQUENCY USING O-D AND MODEL DATA

NON-HOME TRIPS - COMBINATION 3 PARAMETERS

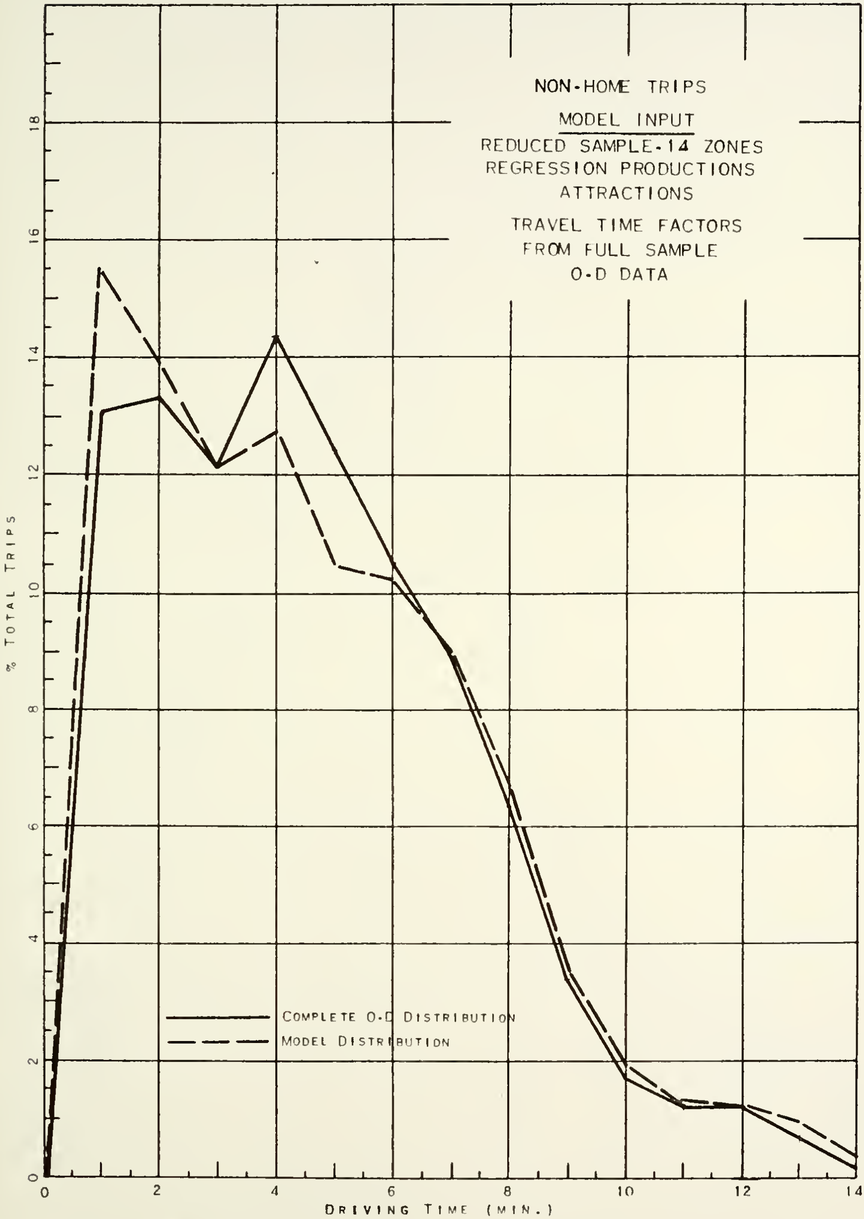


FIGURE 35

COMPARISON OF TRIP LENGTH FREQUENCY USING O-D AND MODEL DATA

HOME-WORK TRIPS - COMBINATION 4 PARAMETERS

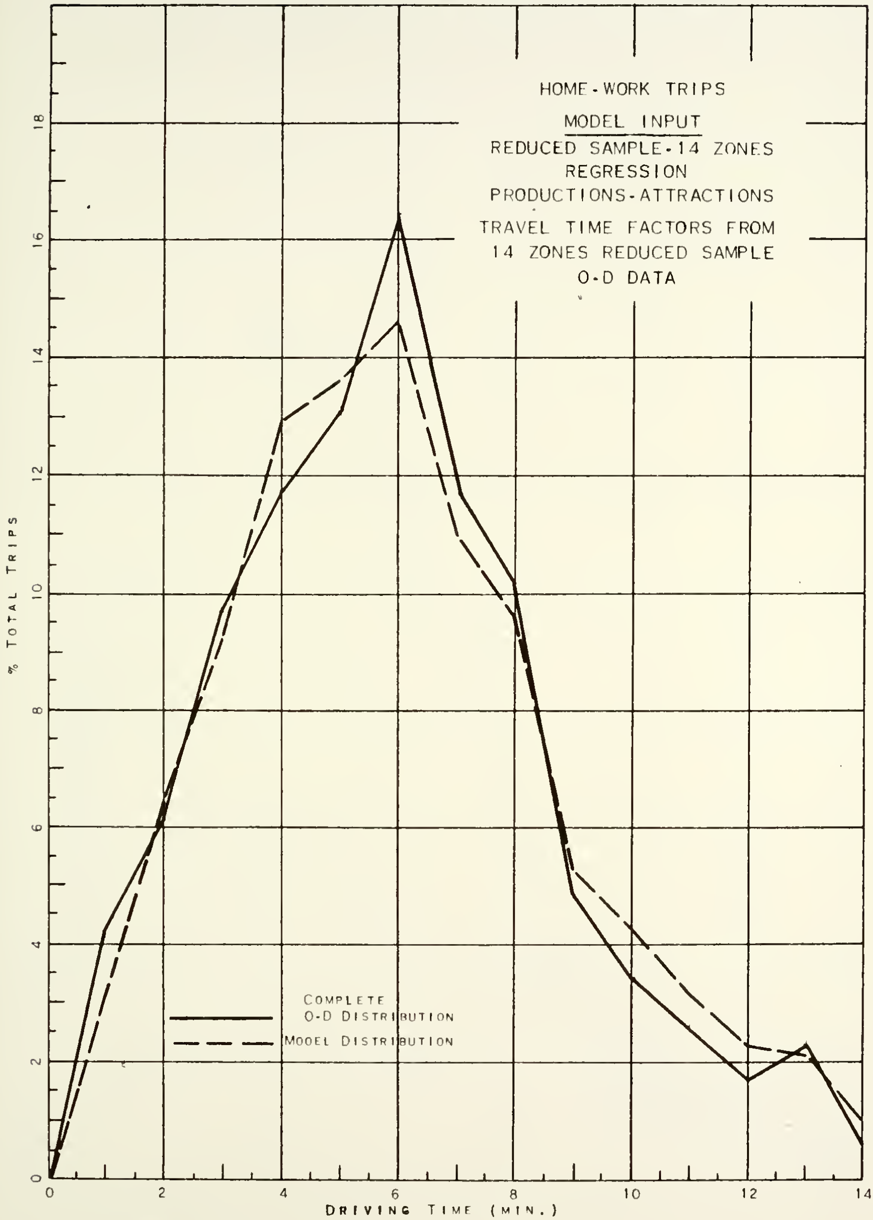


FIGURE 36

COMPARISON OF TRIP LENGTH FREQUENCY USING O-D AND MODEL DATA

HOME-OTHER TRIPS - COMBINATION 4 PARAMETERS

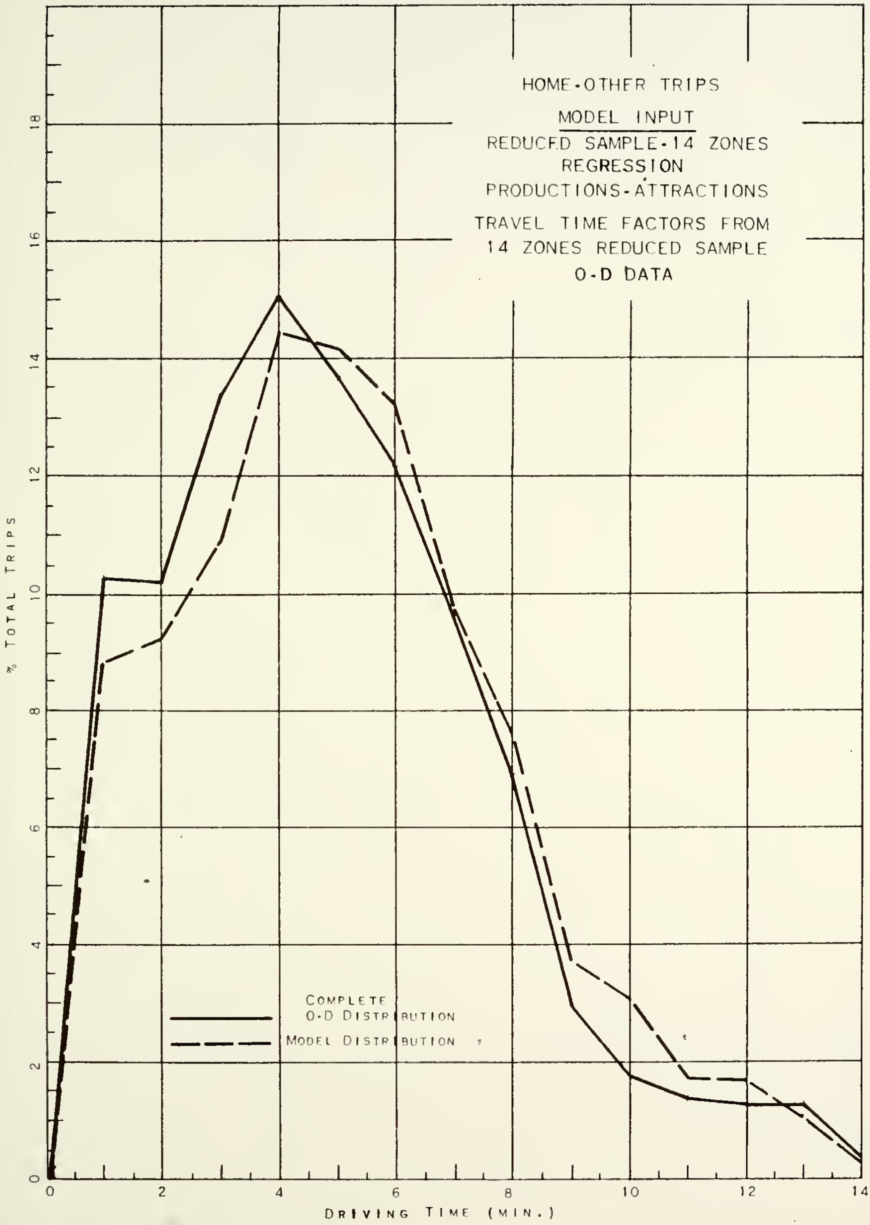


FIGURE 37

COMPARISON OF TRIP LENGTH FREQUENCY USING O-D AND MODEL DATA

NON-HOME TRIPS - COMBINATION 4 PARAMETERS

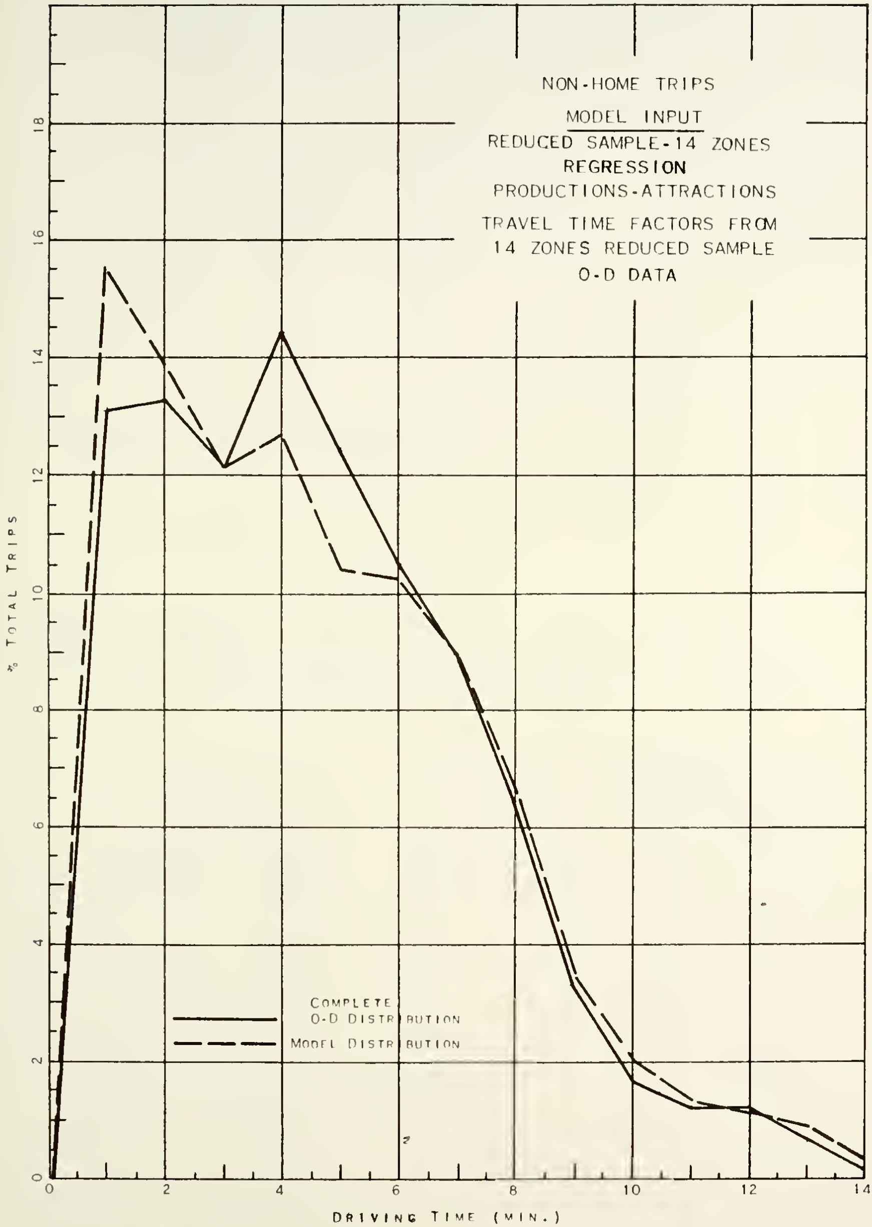


TABLE 30

COMPARISON OF VEHICLE HOURS OF TRAVEL AND AVERAGE TRIP LENGTH FROM O-D AND MODEL DATA USING TRAVEL TIME FACTORS FROM THE FULL SAMPLE O-D DATA

	Complete O-D Survey Data		Full Sample: O-D Productions-Attractions		Full Sample: Regression Productions-Attractions	
Trip Purpose	Vehicle Hours	Average Trip Length*	Vehicle Hours	Average Trip Length*	Vehicle Hours	Average Trip Length*
Home-Work	1831	6.06	1823	6.03	1970	6.01
Home-Other	2584	4.91	2610	4.95	2845	5.22
Non-Home	1597	4.48	1657	4.64	1823	4.60

* Average Trip Length in Minutes/Trip

TABLE 31

COMPARISON OF VEHICLE HOURS OF TRAVEL AND AVERAGE TRIP LENGTH FROM O-D AND MODEL DATA USING TRAVEL TIME FACTORS FROM THE 14 SELECTED ZONES REDUCED SAMPLE O-D DATA

	Complete O-D Survey Data		Reduced Sample: O-D Productions-Attractions		Reduced Sample: Regression Productions-Attractions	
Purpose	Vehicle Hours	Average Trip Length*	Vehicle Hours	Average Trip Length*	Vehicle Hours	Average Trip Length*
Home-Work	1831	6.06	1842	6.09	2028	6.18
Home-Other	2584	4.91	2627	4.98	2855	5.24
Non-Home	1597	4.48	1657	4.64	1823	4.60

* Average Trip Length in Minutes/Trip

TABLE 32

COMPARISON OF VEHICLE MILES OF TRAVEL AND AVERAGE TRIP LENGTH FROM O-D AND MODEL DATA USING TRAVEL TIME FACTORS FROM THE FULL SAMPLE O-D DATA

	Complete O-D Survey Data		Full Sample: O-D Productions -Attractions		Full Sample: Regression Productions-Attractions	
Trip Purpose	Vehicle Miles	Average Trip Length*	Vehicle Miles	Average Trip Length*	Vehicle Miles	Average Trip Length*
Home-Work	35331.6	1.946	35325.6	1.947	38327.3	1.948
Home-Other	48248.2	1.527	49193.3	1.552	54894.9	1.680
Non-Home	30755.6	1.438	30630.7	1.431	33731.9	1.419

* Average Trip Length in Mi./Trip

TABLE 33

COMPARISON OF VEHICLE MILES OF TRAVEL AND AVERAGE TRIP LENGTH FROM O-D AND MODEL DATA USING TRAVEL TIME FACTORS FROM THE 14 SELECTED ZONES REDUCED SAMPLE O-D DATA

	Complete O-D Survey Data		Reduced Sample: O-D Productions -Attractions		Reduced Sample: Regression Productions-Attractions	
Trip Purpose	Vehicle Miles	Average Trip Length*	Vehicle Miles-	Average Trip Length*	Vehicle Miles	Average Trip Length*
Home-Work	35331.6	1.946	35765.0	1.971	40007.6	2.033
Home-Other	48248.2	1.527	49454.6	1.563	54882.0	1.679
Non-Home	30755.6	1.438	30636.7	1.431	33717.9	1.418

* Average Trip Length in Mi./Trip

vehicle miles of travel was taken as the product of the zone interchange and the "L" distance between the zone centroids in question with the summation being made over all zones. The average trip length in miles was taken as the total vehicle miles of travel divided by the total number of trips.

Comparison of District to District Movements

A comparison also was made of the district to district movements given by both the model and O-D data. The comparison was originally made using zone to zone movements but the small numbers of trips gave results having little stability. Table 19 indicates the zones that were contained in the various districts. The RMS errors for the various volume groups and trip purposes, as shown in Tables 34 through 43, indicate that two-thirds of the time the difference between district interchanges, as given by the model and O-D data, is expected to be equal to, or less than, the value of the RMS error.

District-to-district trip interchanges can be used in determining interchange volumes between the CBD and various "corridors". This can provide a check on the geographical bias of the model. However, in this analysis, it was felt that the "screenline" checks gave a dependable test for bias.

TABLE 34

ANALYSIS OF DISTRICT TO DISTRICT/1 MOVEMENTS

HOME - WORK TRIPS, FULL SAMPLE, COMPLETE O-D PRODUCTIONS-ATTRACTIONS, TRAVEL TIME FACTORS FROM REDUCED SAMPLE O-D DATA

Volume Group	Freq/2	Total Trips		Mean Difference	Standard Deviation	RMS Error	% RMS Error
		O-D	Model				
0-99	106	4,803	5,718	-8	27	28	63
100-199	26	3,644	3,380	10	48	49	35
200-299	5	1,236	1,053	36	90	98	39
300-399	6	2,122	2,170	-8	51	52	14
400-499	4	1,828	1,779	12	54	56	12
500-599	2	1,112	1,087	12	79	80	14
600-699	1	607	525	82	---	81	13
700-799	---	---	---	---	---	---	---
800-899	1	844	891	-47	---	46	5
900-999	---	---	---	---	---	---	---
1000-1499	---	---	---	---	---	---	---
1500-1999	1	1,691	1,355	336	---	335	19
2000-2999	---	---	---	---	---	---	---
3000-3999	---	---	---	---	---	---	---
4000-4999	---	---	---	---	---	---	---
5000-5999	---	---	---	---	---	---	---
6000-6999	---	---	---	---	---	---	---
7000-7999	---	---	---	---	---	---	---
8000-8999	---	---	---	---	---	---	---
9000-9999	---	---	---	---	---	---	---
10000-999999	---	---	---	---	---	---	---
TOTAL		17,887	17,958				

/1 See Table 19 for zones making up each district.
/2 Number of district to district movements within the volume group.

TABLE 35

ANALYSIS OF DISTRICT TO DISTRICT[1] MOVEMENTS

HOME - OTHER TRIPS, FULL SAMPLE, COMPLETE O-D PRODUCTIONS-ATTRACTIONS, TRAVEL TIME FACTORS FROM REDUCED SAMPLE O-D DATA

Volume Group	Freq[2]	Total Trips		Mean Difference	Standard Deviation	RMS Error	% RMS Error
		O-D	Model				
0-99	79	3,483	4,227	-9	29	30	69
100-199	31	4,303	4,796	-15	54	57	41
200-299	10	2,455	2,653	-19	122	123	50
300-399	7	2,340	2,296	6	101	101	30
400-499	7	3,191	2,580	87	135	161	35
500-599	6	3,312	3,456	-24	95	98	17
600-699	5	3,201	3,329	-25	139	141	22
700-799	2	1,459	1,628	-84	245	259	35
800-899	2	1,671	1,019	326	100	341	40
900-999	2	1,913	2,234	-160	74	176	18
1000-1499	---	---	---	---	---	---	---
1500-1999	1	1,669	1,779	-110	---	109	6
2000-2999	1	2,150	1,457	693	---	692	32
3000-3999	---	---	---	---	---	---	---
4000-4999	---	---	---	---	---	---	---
5000-5999	---	---	---	---	---	---	---
6000-6999	---	---	---	---	---	---	---
7000-7999	---	---	---	---	---	---	---
8000-8999	---	---	---	---	---	---	---
9000-9999	---	---	---	---	---	---	---
10000-999999	---	---	---	---	---	---	---
TOTAL		31,147	31,454				

[1] See Table 19 for zones making up each district.
[2] Number of district to district movements within the volume group.

TABLE 36

ANALYSIS OF DISTRICT TO DISTRICT/1 MOVEMENTS

NON - HOME TRIPS, FULL SAMPLE, COMPLETE O-D PRODUCTIONS-ATTRACTIONS, TRAVEL TIME FACTORS FROM REDUCED SAMPLE O-D DATA

Volume Group	Freq/2	Total Trips O-D	Total Trips Model	Mean Difference	Standard Deviation	RMS Error	% RMS Error
0-99	112	4,185	4,504	-2	21	22	59
100-199	16	2,080	1,863	13	27	30	23
200-299	11	2,702	2,523	16	66	68	27
300-399	3	1,031	955	25	49	55	16
400-499	2	923	793	65	6	65	14
500-599	3	1,747	1,868	-40	63	75	12
600-699	---	---	---	---	---	---	---
700-799	1	783	720	63	---	62	8
800-899	---	---	---	---	---	---	---
900-999	2	1,963	2,053	-45	3	45	4
1000-1499	2	2,427	2,381	23	47	53	4
1500-1999	---	---	---	---	---	---	---
2000-2999	---	---	---	---	---	---	---
3000-3999	1	3,335	3,522	-187	---	186	5
4000-4999	---	---	---	---	---	---	---
5000-5999	---	---	---	---	---	---	---
6000-6999	---	---	---	---	---	---	---
7000-7999	---	---	---	---	---	---	---
8000-8999	---	---	---	---	---	---	---
9000-9999	---	---	---	---	---	---	---
10000-999999	---	---	---	---	---	---	---
TOTAL		21,176	21,182				

/1 See Table 19 for zones making up each district.
/2 Number of district to district movements within the volume group.

TABLE 37

ANALYSIS OF DISTRICT TO DISTRICT[1] MOVEMENTS

ALL TRIPS, FULL SAMPLE, COMPLETE O-D PRODUCTIONS-ATTRACTIONS, TRAVEL TIME FACTORS FROM REDUCED SAMPLE O-D DATA

Volume Group	Freq[2]	Total Trips O-D	Total Trips Model	Mean Difference	Standard Deviation	RMS Error	% RMS Error
0-99	33	1,858	1,929	-2	39	39	69
100-199	32	4,648	5,066	-13	60	61	42
200-299	32	7,875	8,396	-16	98	99	40
300-399	14	4,891	4,970	-5	93	94	26
400-499	8	3,476	3,627	-18	66	69	15
500-599	2	1,089	480	304	83	315	57
600-699	4	2,576	2,484	23	88	91	14
700-799	4	2,943	2,996	-13	182	182	24
800-899	2	1,641	1,750	-54	65	85	10
900-999	2	1,896	1,681	107	92	141	14
1000-1499	10	12,750	12,482	26	315	316	24
1500-1999	4	6,753	6,400	88	228	245	14
2000-2999	4	9,581	10,393	-203	168	263	11
3000-3999	1	3,549	3,853	-304	---	303	8
4000-4999	---	---	---	---	---	---	---
5000-5999	1	5,199	4,087	1,112	---	1,112	21
6000-6999	---	---	---	---	---	---	---
7000-7999	---	---	---	---	---	---	---
8000-8999	---	---	---	---	---	---	---
9000-9999	---	---	---	---	---	---	---
10000-999999	---	---	---	---	---	---	---
TOTAL		70,725	70,594				

[1] See Table 19 for zones making up each district.
[2] Number of district to district movements within the volume group.

TABLE 38
ANALYSIS OF DISTRICT TO DISTRICT/1 MOVEMENTS

HOME - WORK TRIPS, FULL SAMPLE, REGRESSION PRODUCTIONS-ATTRACTIONS, TRAVEL TIME FACTORS FROM REDUCED SAMPLE O-D DATA

Volume Group	Freq/2	Total Trips		Mean Difference	Standard Deviation	RMS Error	% RMS Error
		O-D	Model				
0-99	106	4,803	6,813	-18	31	36	81
100-199	26	3,644	3,655	---	56	56	40
200-299	5	1,236	1,027	41	57	70	28
300-399	6	2,122	2,579	-76	147	166	47
400-499	4	1,828	1,793	8	39	40	8
500-599	2	1,112	1,161	-24	108	111	20
600-699	1	607	455	152	---	151	25
700-799	---	---	---	---	---	---	---
800-899	1	844	996	-152	---	151	18
900-999	---	---	---	---	---	---	---
1000-1499	---	---	---	---	---	---	---
1500-1999	1	1,691	1,089	602	---	601	35
2000-2999	---	---	---	---	---	---	---
3000-3999	---	---	---	---	---	---	---
4000-4999	---	---	---	---	---	---	---
5000-5999	---	---	---	---	---	---	---
6000-6999	---	---	---	---	---	---	---
7000-7999	---	---	---	---	---	---	---
8000-8999	---	---	---	---	---	---	---
9000-9999	---	---	---	---	---	---	---
10000-999999	---	---	---	---	---	---	---
TOTAL		17,887	19,568				

/1 See Table 19 for zones making up each district.
/2 Number of district to district movements within the volume group.

TABLE 39

ANALYSIS OF DISTRICT TO DISTRICT/1 MOVEMENTS

HOME - OTHER TRIPS, FULL SAMPLE, REGRESSION PRODUCTIONS-ATTRACTIONS, TRAVEL TIME FACTORS FROM REDUCED SAMPLE O-D DATA

Volume Group	Freq/2	Total Trips		Mean Difference	Standard Deviation	RMS Error	% RMS Error
		O-D	Model				
0-99	79	3,483	4,959	-18	41	45	102
100-199	31	4,303	5,154	-27	65	70	51
200-299	10	2,455	2,623	-16	100	101	41
300-399	7	2,340	3,123	-111	104	152	45
400-499	7	3,191	2,683	72	186	199	43
500-599	6	3,312	3,226	14	32	35	6
600-699	5	3,201	3,356	-31	60	67	10
700-799	2	1,459	1,602	-71	177	191	26
800-899	2	1,691	946	362	60	367	43
900-999	2	1,913	2,167	-127	150	197	20
1000-1499	---	---	---	---	---	---	---
1500-1999	1	1,669	1,420	249	---	248	14
2000-2999	1	2,150	1,311	839	---	838	39
3000-3999	---	---	---	---	---	---	---
4000-4999	---	---	---	---	---	---	---
5000-5999	---	---	---	---	---	---	---
6000-6999	---	---	---	---	---	---	---
7000-7999	---	---	---	---	---	---	---
8000-8999	---	---	---	---	---	---	---
9000-9999	---	---	---	---	---	---	---
10000-999999	---	---	---	---	---	---	---
TOTAL		31,107	32,570				

/1 See Table 10 for zones making up each district.
/2 Number of district to district movements within the volume group.

TABLE 40

ANALYSIS OF DISTRICT TO DISTRICT[1] MOVEMENTS

NON - HOME TRIPS, FULL SAMPLE, REGRESSION PRODUCTIONS-ATTRACTIONS, TRAVEL TIME FACTORS FROM REDUCED SAMPLE O-D DATA

Volume Group	Freq[2]	Total Trips O-D	Total Trips Model	Mean Difference	Standard Deviation	RMS Error	% RMS Error
0-99	111	4,185	4,831	-5	29	30	80
100-199	16	2,080	2,072	---	54	54	41
200-299	11	2,702	2,463	21	113	115	47
300-399	3	1,031	1,049	-6	43	43	12
400-499	2	923	840	41	33	53	11
500-599	3	1,747	2,019	-90	196	216	37
600-699	---	---	---	---	---	---	---
700-799	1	783	977	-194	---	193	24
800-899	---	---	---	---	---	---	---
900-999	2	1,963	2,203	-120	157	198	20
1000-1499	2	2,427	2,721	-147	97	176	14
1500-1999	---	---	---	---	---	---	---
2000-2999	---	---	---	---	---	---	---
3000-3999	1	3,335	4,523	-1,188	---	1,187	35
4000-4999	---	---	---	---	---	---	---
5000-5999	---	---	---	---	---	---	---
6000-6999	---	---	---	---	---	---	---
7000-7999	---	---	---	---	---	---	---
8000-8999	---	---	---	---	---	---	---
9000-9999	---	---	---	---	---	---	---
10000-999999	---	---	---	---	---	---	---
TOTAL		21,176	23,698				

[1] See Table 19 for zones making up each district.
[2] Number of district to district movements within the volume group.

TABLE 41

ANALYSIS OF DISTRICT TO DISTRICT/1 MOVEMENTS

ALL TRIPS, FULL SAMPLE, REGRESSION PRODUCTIONS-ATTRACTIONS, TRAVEL TIME FACTORS FROM REDUCED SAMPLE O-D DATA

Volume Group	Freq/2	Total Trips O-D	Total Trips Model	Mean Difference	Standard Deviation	RMS Error	% RMS Error
0-99	33	1,858	2,491	19	49	52	93
100-199	32	4,648	6,219	-49	76	90	62
200-299	32	7,875	8,831	-29	89	93	38
300-399	14	4,891	6,075	-84	132	157	44
400-499	8	3,476	4,024	-68	109	129	29
500-599	2	1,089	582	253	158	298	54
600-699	4	2,576	2,883	-76	234	247	38
700-799	4	2,943	2,608	83	143	165	22
800-899	2	1,641	1,800	-79	162	180	22
900-999	2	1,896	1,735	80	77	111	11
1000-1499	10	12,750	12,558	19	328	329	25
1500-1999	4	6,753	6,659	23	289	290	17
2000-2999	4	9,581	10,739	-289	411	503	21
3000-3999	1	3,549	4,837	-1,288	---	1,287	36
4000-4999	---	---	---	---	---	---	---
5000-5999	1	5,199	3,795	1,404	---	1,403	27
6000-6999	---	---	---	---	---	---	---
7000-7999	---	---	---	---	---	---	---
8000-8999	---	---	---	---	---	---	---
9000-9999	---	---	---	---	---	---	---
10000-999999	---	---	---	---	---	---	---
TOTAL		70,725	75,836				

/1 See Table 19 for zones making up each district.
/2 Number of district to district movements within the volume group.

TABLE 42

ANALYSIS OF DISTRICT TO DISTRICT[1] MOVEMENTS

ALL TRIPS, FULL SAMPLE, COMPLETE O-D PRODUCTIONS-ATTRACTIONS, TRAVEL TIME FACTORS FROM FULL SAMPLE O-D DATA

Volume Group	Freq[2]	Total Trips		Mean Difference	Standard Deviation	RMS Error	% RMS Error
		O-D	Model				
0-99	33	1,858	1,965	-3	39	39	70
100-199	32	4,648	5,041	-12	60	61	42
200-299	32	7,875	8,389	-16	99	100	40
300-399	14	4,891	4,915	-1	90	90	25
400-499	8	3,476	3,638	-20	78	81	18
500-599	2	1,089	506	291	85	303	55
600-699	4	2,576	2,517	14	91	92	14
700-799	4	2,943	3,001	-17	196	197	26
800-899	2	1,641	1,757	-58	29	65	7
900-999	2	1,896	1,662	117	85	145	15
1000-1499	10	12,750	12,433	31	294	296	23
1500-1999	4	6,753	6,399	88	251	256	15
2000-2999	4	9,581	10,498	-229	159	279	11
3000-3999	1	3,549	3,868	-319	---	318	8
4000-4999	---	---	---	---	---	---	---
5000-5999	1	5,199	4,018	1,181	---	1,180	22
6000-6999	---	---	---	---	---	---	---
7000-7999	---	---	---	---	---	---	---
8000-8999	---	---	---	---	---	---	---
9000-9999	---	---	---	---	---	---	---
10000-999999	---	---	---	---	---	---	---
TOTAL		70,725	70,607				

[1] See Table 19 for zones making up each district.
[2] Number of district to district movements within the volume group.

TABLE 43

ANALYSIS OF DISTRICT TO DISTRICT/1 MOVEMENTS

ALL TRIPS, FULL SAMPLE, REGRESSION PRODUCTIONS-
ATTRACTIONS, TRAVEL TIME FACTORS FROM FULL SAMPLE O-D DATA

Volume Group	Freq/2	Total Trips		Mean Difference	Standard Deviation	RMS Error	% RMS Error
		O-D	Model				
0-99	33	1,858	2,554	-21	48	52	93
100-199	32	4,648	5,907	-39	83	92	63
200-299	32	7,875	8,752	-27	88	92	37
300-399	14	4,891	6,034	-81	137	160	45
400-499	8	3,476	3,923	-55	116	129	29
500-599	2	1,089	611	239	164	290	53
600-699	4	2,576	2,970	-98	250	269	41
700-799	4	2,943	2,653	72	164	180	24
800-899	2	1,641	1,815	-87	118	147	17
900-999	2	1,896	1,725	85	78	116	12
1000-1499	10	12,750	12,603	14	309	309	24
1500-1999	4	6,753	6,714	9	303	[illegible]	18
2000-2999	4	9,581	10,923	-335	374	502	20
3000-3999	1	3,549	4,846	-1,297	---	1,296	36
4000-4999	---	---	---	---	---	---	---
5000-5999	1	5,199	3,780	1,419	---	1,418	27
6000-6999	---	---	---	---	---	---	---
7000-7999	---	---	---	---	---	---	---
8000-8999	---	---	---	---	---	---	---
9000-9999	---	---	---	---	---	---	---
10000-999999	---	---	---	---	---	---	---
TOTAL		70,725	75,810				

/1 See Table 19 for zones making up each district.
/2 Number of district to district movements within the volume group.

CONCLUSIONS

It is concluded that:

1. Current zonal trip productions and attractions were adequately estimated from mathematical models developed from a small sample of home interviews (selected as recommended by Reference 14) taken in a sample of the origin-destination zones. Best estimates resulted for home-based trip productions but estimated non-home-based trip productions and all trip attractions appeared to be adequate for planning purposes.
2. Mathematical models developed from current comprehensive O-D or reduced sample data should be of great value in estimating future zonal trip productions and attractions.
3. Only three trip purposes-home-work, home-other, and non-home were found to be practical divisions of all trips for prediction of zonal trip productions and attractions from mathematical models based on comprehensive or reduced sample O-D data.
4. For home-work trip attractions, the number of jobs in a zone was the only important factor.

5. For home-work trip productions, the number of employed persons per dwelling unit was not found to be a more important factor than persons per dwelling unit.
6. For all trip productions, the number of persons and the number of cars per dwelling unit were found to be very important factors. Other factors of importance for trip productions were distance to the CBD for home-work and home-other trips and area of various land uses and number of jobs for non-home trips.
7. For trip attractions other than the home-work trip, the number of persons per zone, the number of various types of jobs in the zone, and the areas devoted to various land uses were found to be important factors.
8. Travel time factors for distribution of trips by the gravity model were satisfactorily estimated by calibrating the gravity model with trip length frequency data developed from a small sample of home interviews taken in a sample of the O-D zones.
9. The travel time factors which were developed varied in value for the different trip purposes for the same travel-time separation.
10. The gravity model using trip productions and attractions and travel time factors developed from a small sample of home interviews taken in a sample of O-D zones distributed trips among all zones to give an adequate reproduction for planning purposes of the trip distribution

obtained in a comprehensive O-D survey.

11. The gravity model using trip productions and attractions and travel time factors developed from a comprehensive O-D survey distributed trips among all zones to give a good reproduction of the trip distribution obtained in the comprehensive survey.

RECOMMENDATIONS FOR FURTHER RESEARCH

It is felt that further research is needed in developing a usable mathematical function for travel time factors. Some recent research conducted in this area is discussed in reference (17).

It is believed that trip production and attraction studies among a number of smaller cities in the same geographical region may well yield similar estimating equations based upon zonal characteristics alone. A brief investigation indicated that Hutchinson production equations when applied to Pittsburg, Kansas, zonal data yielded productions that compared favorably with Pittsburg travel data.

In addition, such studies can be expected to yield information concerning the reasons for the similarities and differences among the equations developed for the various cities. Truck trips as well as auto trips should be studied.

If trip productions and attractions can be reliably estimated in this manner, then it would remain necessary only to determine the trip length frequency in order to calibrate a gravity model. If the gravity model research currently being carried out at North Carolina State University indicates that one can, using a small random sample O-D survey, determine satisfactory trip length information, then the Hutchinson data and computer programs developed in this research project should enable one to determine the minimum sampling rate applicable to Hutchinson in a relatively short time.

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LIST OF REFERENCES

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APPENDIX A

HUTCHINSON KANSAS

METROPOLITAN AREA TRANSPORTATION STUDY

LAND USE SURVEY

FIELD INSTRUCTIONS AND CODE MANUAL

KANSAS STATE HIGHWAY COMMISSION

INTRODUCTION

The information will be inventoried and summarized on a census tract, or zone, and block basis. Two tabulating cards will be used for summarizing the data.

Card 1 will contain the block statistical data.
Card 2 will detail the land uses by area in thousands of square feet.

Card columns 1 to 10 inclusive are identification columns and will be common to both cards.

Card columns 11 to 29 inclusive are block statistical data and will be punched in card 1 only.

Card columns 11 to 29 inclusive will be blank on Card 2.

CARD 1 and CARD 2

Card Col.	Item
1 - 2	Year of survey
3 - 4	City being studied. Code the project number assigned to the city. (For Hutchinson, this is 95)
5	Sub-area. Metropolitan area sub-divisions.

Code	Area
1	Inside major city limits
2	Unincorporated
3	Minor city

Card Col.	Item
6 - 7	Tract or zone. From metropolitan area map.
8	Sub-zone. Code "O" for Hutchinson.
9 - 10	Block number. From metropolitan area map.

Coding instructions - continued

LAND USE

For multi-storied buildings and for single storied buildings with two or more businesses on the ground floor, use a line, not to be coded or punched, to name the building, and enter dimensions and gross area under "Description". This data will be used only for checking total areas of detailed land uses by floors. Inventory the first floor of multi-storied buildings before the basement or upper floors.

Description: Filed - describe the uses of an area or the floor of a building. Enter each use on a separate line.

Card Col.	Item	
36 - 38	Office coding:	Use the land use code in appendix.
39 - 40	" "	Use codes set up for the city's zoning.

BUILDING FIRST FLOOR OR OPEN GROUND

Field form: First floor of building or open ground
Dimensions: Enter dimensions of each land use

41 - 45 Enter the calculated area to the nearest 1000 square feet

Note: For business buildings with more than one use on a floor, the total area must equal the calculated gross area shown on the heading line for the building.

BUILDING FLOORS OFF THE GROUND
(including basements where applicable)

Enter a separate line for each use.
Enter dimensions for each use OR percentage of gross floor area.

41 - 45 Area: Code area to nearest 1000 square feet and punch in col. 41-45. Note: Calculated floor area for each use must equal gross floor area.

Coding instructions - continued

Note 1: Block totals at bottom of column headed "Building 1st Floor, or Open Ground Area" should equal the line headed "Net for other uses".

Note.2: Sum of the 2 total blocks gives total area usage except streets and alleys.

LAND USES AND CODES

MAJOR GROUPS

0	Residential
1	Manufacturing
	10 - Heavy 11 - Other
2	Retail Trade
3	Wholesale and Warehouse
4	Transportation
5	Construction
6	Personal, Business, Repair Services and Office
7	Government and Utility
8	Other open space - streets, alleys, rivers, lakes, etc.
9	Recreation and Institution

Residential (000 series)

000	Vacant land zoned residential
010	Unclassified
020	Single dwelling unit - detached
030	Single dwelling unit - attached
	Multiple dwelling units
041	3 - 19 units
042	20 or more units
050	Rooming and boarding houses
060	Hotels
070	Motels, tourist homes, tourist camps
080	Trailer courts or camps

Residential (000 series) continued

090	Dormitories, lodging houses on a membership basis

Manufacturing Industries - Heavy (100 series)

101	Mining, quarrying, and other extracting industries
102	Lumber and wood products, except furniture
103	Stone, clay and glass products
104	Metal products
105	Machinery
106	Chemical and allied products
107	Petroleum refining and related industries
108	Paper and allied products
109	Transportation equipment

Manufacturing Industries - Other (110 series)

110	Furniture and fixtures
111	Professional, scientific, and controlling instruments; photographic and optical goods; watches and clocks
112	Textile mill and apparel products
113	Printing, publishing and allied industries
114	Food and kindred products
115	Rubber and miscellaneous products
116	Tobacco products
117	Leather and leather products
118	Miscellaneous manufacturing industries
119	Vacant land zoned industrial

Retail Trade (200 series)

200 Vacant land zoned commercial

210 Unclassified retail outlets

220 Super food markets

221 Other food establishments

230 Drug stores, eating and drinking establishments

240 Department store and general merchandise stores

250 Apparel and accessories stores

260 Furniture, home furnishings and appliance stores

270 Motor vehicle and vehicle accessories stores; boats and marine equipment; farm equipment. (Sales and Service)

280 Gasoline service stations

290 Lumber and building materials and hardware stores

Wholesale and Warehouse (300 series)

300 Unclassified

310 Wholesalers with stock

320 Wholesalers without stock

330 Warehousing and storage

Transportation (400 series)

400 Unclassified

410 Railroad terminals

420 Railroad yards

430 Local and interurban mass transportation, school buses and taxicabs

440 Air transportation

450 Motor freight transportation

460 Other transportation (water and pipeline)

Construction (500 series)

500	Unclassified
510	General highway and heavy construction contractors with storage yards for construction and maintenance equipment and oil field construction equipment.
520	General building contractors with storage yards for construction and maintenance equipment.
530	General wrecking concerns and storage yards
540	Special trades contractors (electrical, plumbing, etc.)
550	Buildings (all types) under construction

Personal Business, Repair Services and Offices (600 series)

600	Miscellaneous repair and service
610	Personal services
620	Business services
630	Parking services
640	Automobile repair and service
650	Unclassified offices
660	Financial, insurance, and real estate - offices
670	Medical and health services - "
680	Other professional services - "

Government and Utility (700 series)

700	Communication
710	Utilities (electric, gas and sanitary service)
720	Post Offices and government, operational
730	Government, administrative and legal
740	Military

APPENDIX B

DESCRIPTIONS OF COMPUTER PROGRAMS WRITTEN FOR THIS RESEARCH PROJECT

TITLE: SAMPLE SELECTOR FOR TRIP PRODUCTION
DECK No. 110-27GM

Prog. 110-27GM prepares cards in proper input form for "SCRAP"

Regression Analysis Program for use in developing estimating equations for trip productions. Input is O-D survey Card 1 and Card 2 in order by zone.

TITLE: HOME BASED TRIP ATTRACTIONS
DECK No. 110-04GM

Prog. 110-04GM expands the home based trip attraction data in O-D survey Card 2. Input cards are sorted onEAM. Output is cards.

TITLE: NON-HOME BASED PRODUCTIONS AND ATTRACTIONS
DECK No. 110-06GM

Prog. 110-06 GM expands the non-home based trip production and attraction data in O-D survey Card 2. Trip productions are expanded manually and the input cards are sorted on EAM. Output is cards.

TITLE: O-D SAMPLE RATE REDUCER
DECK No. 110-07GM

Prog. 110-07GM utilizes O-D survey Card 1 and Card 2 in selecting the desired per cent of the original sample size.

TITLE: TRIP LENGTH FREQUENCY
DECK No. 110-10GM

Prog. 110-10GM utilizes the output from the Missouri Tree Building Program for zone to zone movements and accumulates the trips by time interval (up to 40 min.) and trip purpose. Input may be either the O-D survey Card 1 and Card 2 or the output Card 1 from the Gravity Model (Prog. 110-05GM) Output is cards.

TITLE: TRIP LENGTH FREQUENCY CONDENSER
DECK No. 110-15GM

Prog. 110-15GM utilizes the output cards of Prog. 110-10GM as input and computes and types out by trip purpose the per cent trips by time interval (up to 40 minutes), the total number of trips, the vehicle minutes of travel and the average trip length in minutes.

TITLE: GRAVITY MODEL DISTRIBUTION
DECK No. 110-05GM

Prog. 110-05GM distributes the input trip productions and attractions to the zones and lists the observed and calculated values of productions and attractions by zone. Input consists of the total number of zones, inter-zonal travel times, K-Factors (not used), productions, attractions and terminal times, and travel time factors.

TITLE: SCREENLINES - GM
DECK No. 110-20GM

Prog. 110-20GM tabulates the number of trips crossing a screenline for a single gravity model purpose. Input consists of the output Card 1 from the Gravity Model (Prog. 110-05GM) and a deck containing the zones on each side of the screenline. Output is cards.

TITLE: SCREENLINES - O-D
DECK No. 110-21GM

Prog. 110-21GM tabulates the number of trips crossing a screenline for each of up to five (5) general purposes and total trips. Input consists of the O-D survey Card 2 - Card 1 may be included but is overlooked by the computer. Output is cards.

TITLE: VEHICLE-MILES O-D
DECK No. 110-40GM

Prog. 110-40GM computes to 0.1 mile the "L" distance from the centroid of the zone of origin to the centroid of the zone of destination. Input consists of the x and y coordinates of each zone centroid and the O-D summary cards from Prog. 110-102 GM. Vehicle miles of travel are typed out.

TITLE: VEHICLE MILES GM
DECK No. 110-41GM

Prog. 110-41GM computes to 0.1 mile the "L" distance from the centroid of the zone of production to the centroid of the zone of attraction. Input consists of the s and y coordinates of each zone centroid and the output Card 1 from Prog. 110-05GM.

TITLE: POLYNOMIAL OF BEST FIT
DECK No. 110-30GM

Prog. 110-30GM computes the desired degree of polynomial to best fit a given set of points (x-y coordinates). The co-efficient of each term and the RMS error are typed out and the x-y coordinates, input and computed, are punched out.

TITLE: EQUATION EVALUATION
DECK No. 110-35GM

Prog. 110-35GM, utilizing the coefficients from the Multiple Regression Analysis "SCRAP" and the values of the variables in the equation, solves the equation for the dependent variable. Output is cards.

TITLE: REFORMAT O-D VOLUMES (HIGH ZONE TO LOW ZONE)
DECK No. 110-50GM

Prog. 110-50GM reformats the O-D survey Card 2 so that all trips go from high numbered zones to low numbered zones, resulting in two cards for each combination, i.e., the original trips from the high zone to the low zone plus the reverse trips between the same zones with the trip ends interchanged. Output is cards.

TITLE: COMBINE O-D VOLUMES
DECK No. 110-102GM

Prog. 110-102GM combines the two output cards from Prog. 110-50GM into one, with all trips from high to low numbered zones. Output is cards.

TITLE: PAIR OD-GM VOLUMES
DECK No. 110-103GM

Prog. 110-103GM requires as input the reformatted and combined O-D data output from Prog. 110-102GM and the output Card 1 from Prog. 110-05GM. This program combines the gravity model volume to two-way and pairs the corresponding O-D and GM two-way volumes between each pair of zones. Output is cards

TITLE: COMPARISON ANALYSIS
DECK No. 110-104GM

Prog. 110-104GM, using the paired volumes from Prog. 110-103GM, accumulates by volume groups a table of differences by differences groups. It then computes for each volume group the frequency of differences, the mean difference, the standard deviation of the differences, the RMS error, the per cent RMS error and the total number of O-D and GM trips. Output is cards.

TITLE: CARD CONVERSION (GM TO TRAFFIC ASSIGNMENT)
DECK No. 110-110GM

Prog. 110-110GM converts the output Card 1 from Prog. 110-05GM to input format for the Missouri Traffic Assignment Program. Output is cards.

TITLE: STATISTICAL TEST OF REGRESSION ESTIMATES
DECK No. 110-106GM

Prog. 110-106GM computes and types out RMS error and per cent RMS error of estimated productions or attractions versul O-D productions or attractions.

The following programs were used but were not written for this project:

SCRAP, Sixteen-twenty Card Regression Analysis Program, IBM Program Library File No. 6.0.003.

A multiple regression analysis program capable of handling a maximum of 23 variables and was used in the development of estimating equations.

The battery of programs, originally written by the Missouri Highway Commission, for traffic assignment was utilized in the determination of "time trees" for the Gravity Model Districution (Prog. 110-05GMO) and Trip Length Frequency (Prog. 110-10GM) Programs.

VITA

VITA

Bob L. Smith was born January 26, 1926 in Topeka, Kansas. He received his primary education at a country school near Emporia, Kansas, and was graduated from Emporia High School in 1943.

He entered Kansas State University in 1943 and spent one semester there. He completed a year's work at Kansas State Teachers College, Pittsburg, Kansas in 1944 in a naval training program. After returning from the navy as an ensign, USNR, in 1946, he entered Kansas State University again, and received his B.S.C.E. degree (with honor) in 1948. He received his M. S. degree in 1953 from Kansas State University.

In 1948, he was a student instructor in the Department of Applied Mechanics at Kansas State, and in 1949 he became an instructor in that department. Since 1950, he has been a member of the Civil Engineering faculty at Kansas State, and presently holds the rank of Associate Professor. In 1959, he was granted a National Science Faculty Fellowship and completed the coursework required for the Ph. D. in the School of Civil Engineering at Purdue University.

He is an associate member of the American Society of Civil Engineers, a registered professional engineer in Kansas, a member of the National Society of Professional Engineers, a member of the Kansas Engineering Society, and a member of the American Society for Engineering Education. He is a member of the following honorary organizations: Sigma Tau, Kappa Mu Epsilon, and Phi Kappa Phi.